

WAVE LOADING ANALYSIS  
OF LAKE WASHINGTON BRIDGES

VOLUME II  
ANALYSIS AND RESULTS  
NEW I-90 FLOATING BRIDGE

File No. 8306  
May 1983

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OF LAKE WASHINGTON BRIDGES

VOLUME II  
ANALYSIS AND RESULTS  
NEW I-90 FLOATING BRIDGE

PREPARED FOR  
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION  
BRIDGE & STRUCTURES ENGINEER  
Under Consulting Agreement Y-2615

in collaboration with  
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## Introduction

This volume (Volume II), of a four volume set, describes the specific dynamic modeling of the new I-90 floating bridge and presents the results of the analysis which was conducted to determine wave induced structural loads and motions. Site-specific wave climatology results, which are also used in the Lacey V. Murrow Bridge analysis, are discussed in this volume.

Volume I describes the general theoretical background of the analysis and documents the general methods employed. Various parametric studies of the I-90 Bridge used to select the values of parameters for final analysis, are also discussed in Volume I.

The principal objective of this work has of course been the development of detailed load data, for use in final structural analysis of the bridge. The structural implications of the results are beyond the scope of this study but, in general, the results seem to be in good agreement with expectations.

Several general conclusions, regarding the analytical methods and the behavior of the structure, have been drawn in the course of this work.

- As discussed in Volume I, the results are quite sensitive to the assumed value of structural damping. This is a manifestation of the fact that the bridge is very large, relative to the scale of the wave system, and therefore its response is almost entirely elastic. Its net free body response is essentially zero, and the customary damping and restoring effects of the fluid on a floating body are not predominant in this case.
- The accuracy of the numerical results will clearly be affected by the scale of discretization of the structure and processes (principally node spacing and frequency mesh). The physical processes are represented mathematically by integrals. But in the numerical analysis, these integrals are then represented by discrete summations. The cost of the analysis is of course very sensitive to the number of nodes and frequencies considered. Our review of the results suggests that our choices were reasonable, and we do not plan to change the level of discretization of the other two bridges to be analyzed.

## 11. Geometry

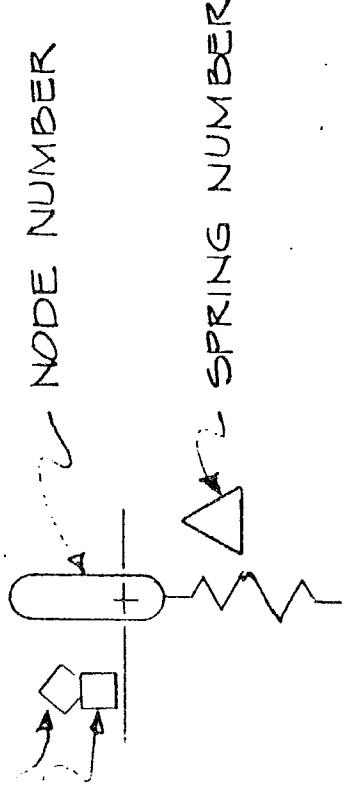
Figure 1 is the nodal map for the new I-90 bridge which shows the geometry of the analytical model. The x-origin is located at the mid-length of cross-pontoon "A", coordinate 119+72.88, positive x to the east. The y-origin is at the pontoon centerline, rather than the lane centerline, positive north. The z-origin is at the design waterline, positive upwards.

Nodes are 35.383 ...feet on center for Pontoons B through Q. This provides 10 elements per pontoon along the major axis. Elements project from the centerline to pick up the anchor cables at the intersection of the line of action of the cable and the x-y (waterline) plane. Pontoons A and R have similar longer elements to attach their anchor cables. The nodes are located vertically at the flexural center of the bridge elements, rather than at the z-origin.

Node 208 through 298 are used as reference nodes to indicate the direction of the anchor cable springs. The spring stiffness is input directly and thus is independent of the distance between the attachment node and its reference node. These nodes have the coordinates of the reference nodes plus or minus some sine and cosine terms.

Additional geometric data are given in Table 12-3.

ELEMENT TYPE  
ELEMENT NUMBER



SPRING & ATTACHMENT  
NODE WHERE RESPONSE  
IS OUTPUT.  
NODE WHERE RESPONSE  
IS OUTPUT.

NODE WHERE HIGHER  
ORDER RESPONSES ARE  
COMPUTED.

KEY PLAN

NOTES:

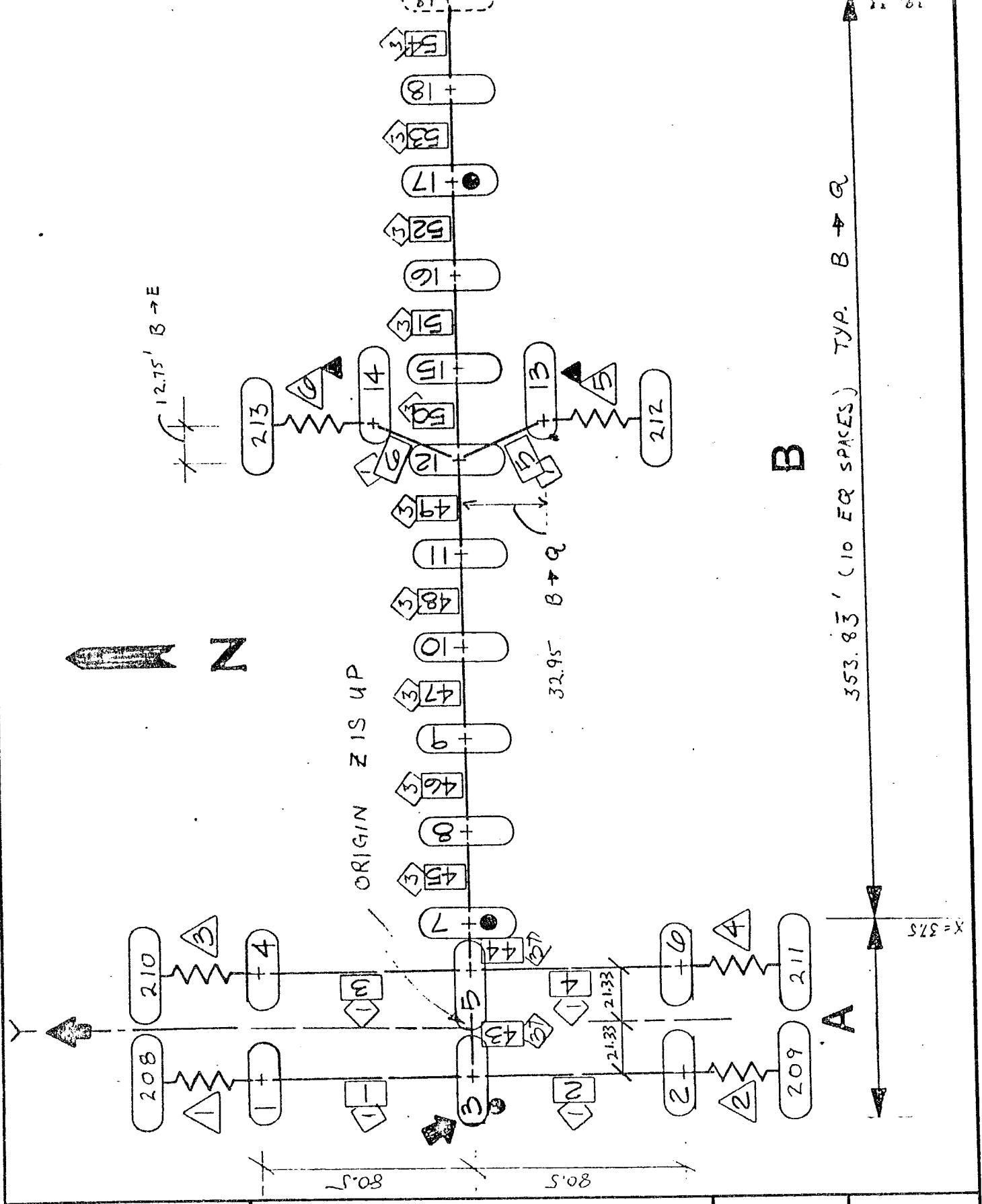
1. NODES ALONG X AXIS ARE SPRING SUPPORTED, EXCEPT # 106 IS FIXED AGAINST X TRANSLATION.
2. NODES 208 → 248 ARE FIXED.
3. ALL SPRINGS & OFF X AXIS MEMBERS ARE MASSLESS.
4. THE HYDRO TERMS ARE ADDED AT X AXIS NODES.
5. RAISED ROADWAY IS ASSUMED NOT TO CONTRIBUTE STIFFNESS, LIKewise THE END SPANS & THE 1½" OVERLAY GROSS UNCRACKED CONCRETE SECTIONS ARE USED
6. IN COMPUTING STIFFNESS SECTION PROPERTIES, NODES AT INBOARD ENDS OF SPRING Z = 0
7. DIMENSIONS ARE IN FEET.
8. STRUCTURAL DAMPING HAS BEEN VARIED - SEE REPORT.
9. NODE 110 HAS ADDED X & TRANSLATION SPRING ATTACHED THERE.
10. ADDED TO REPRESENT ANCHOR CABLES

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NEW I-90

FIG. 11-1 SHT. 2/19

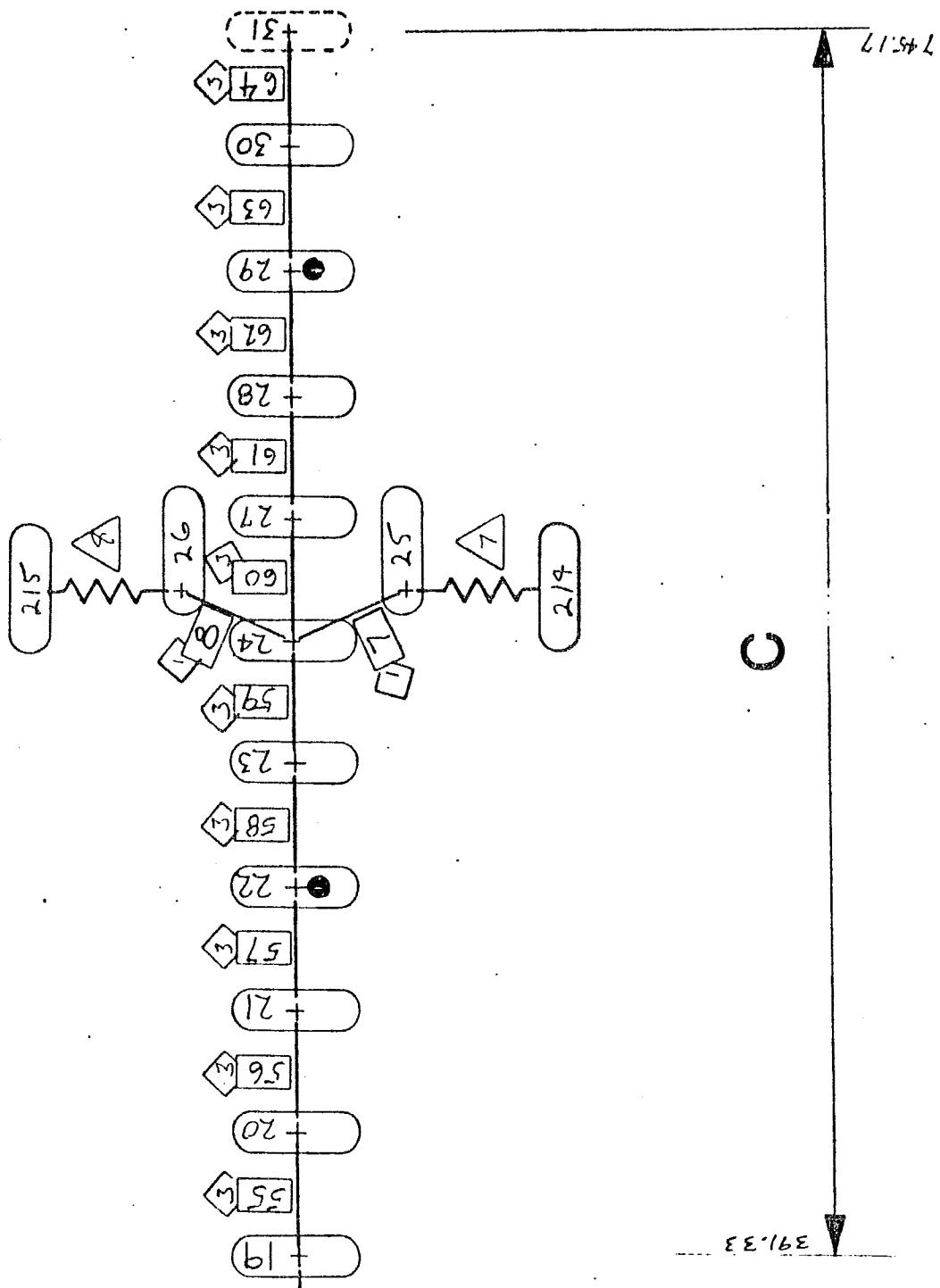


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NEW I-90

FIG. 11-1 SHT. 3/19

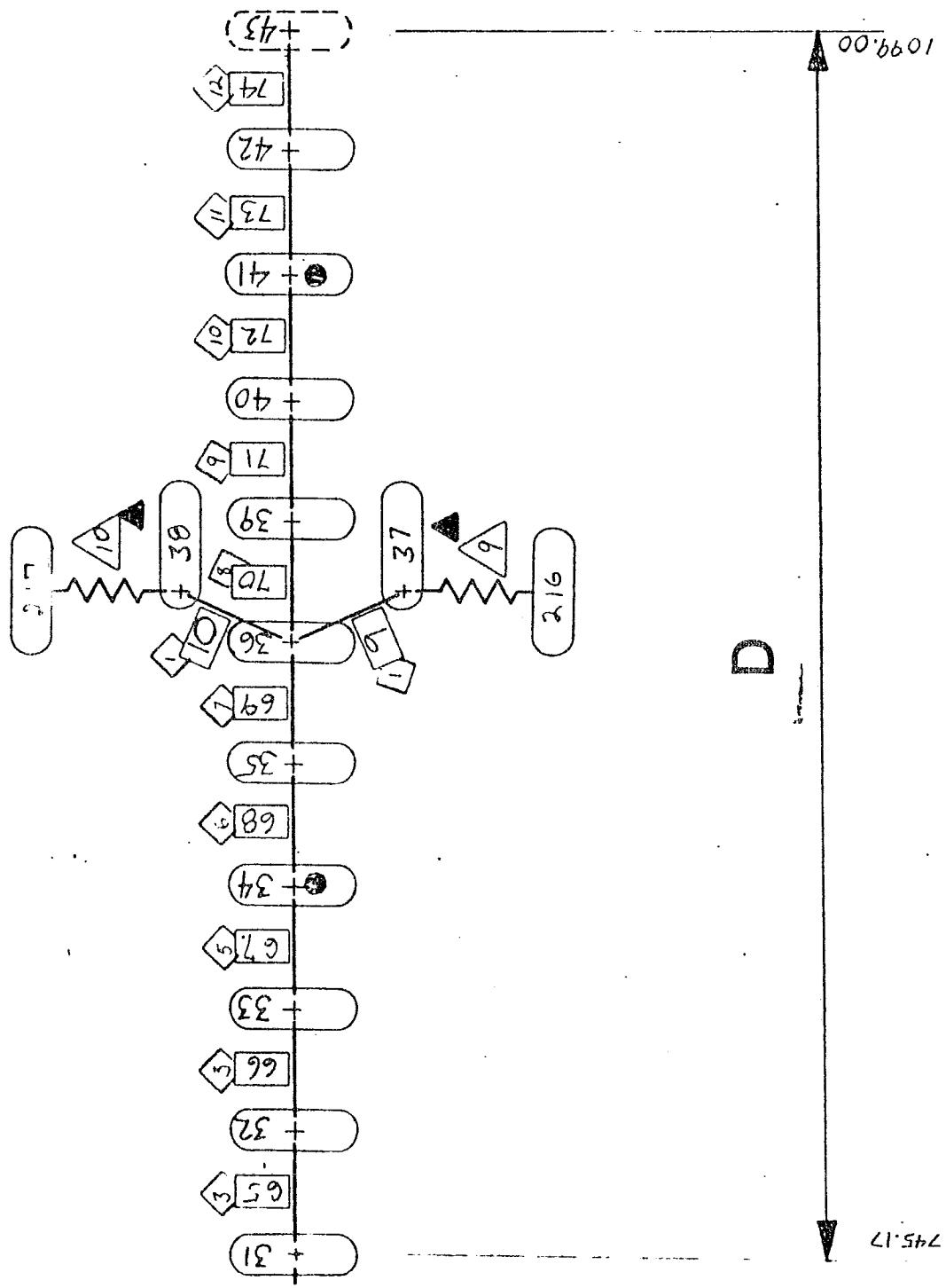


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NEW I-90

FIG. 11-1 SHT. 4/19

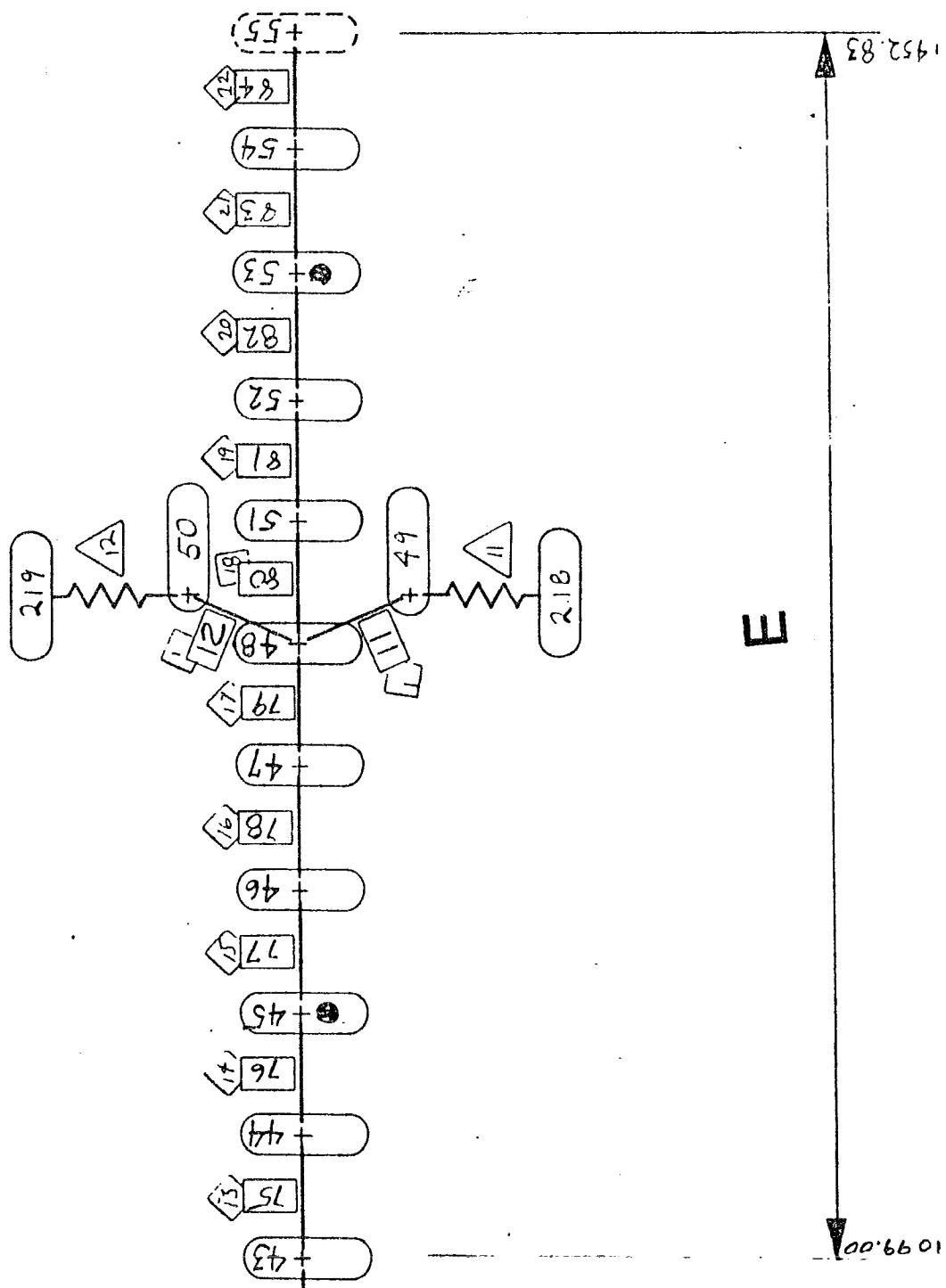


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NEW I-90

FIG. 11-1 SHT. 5/19

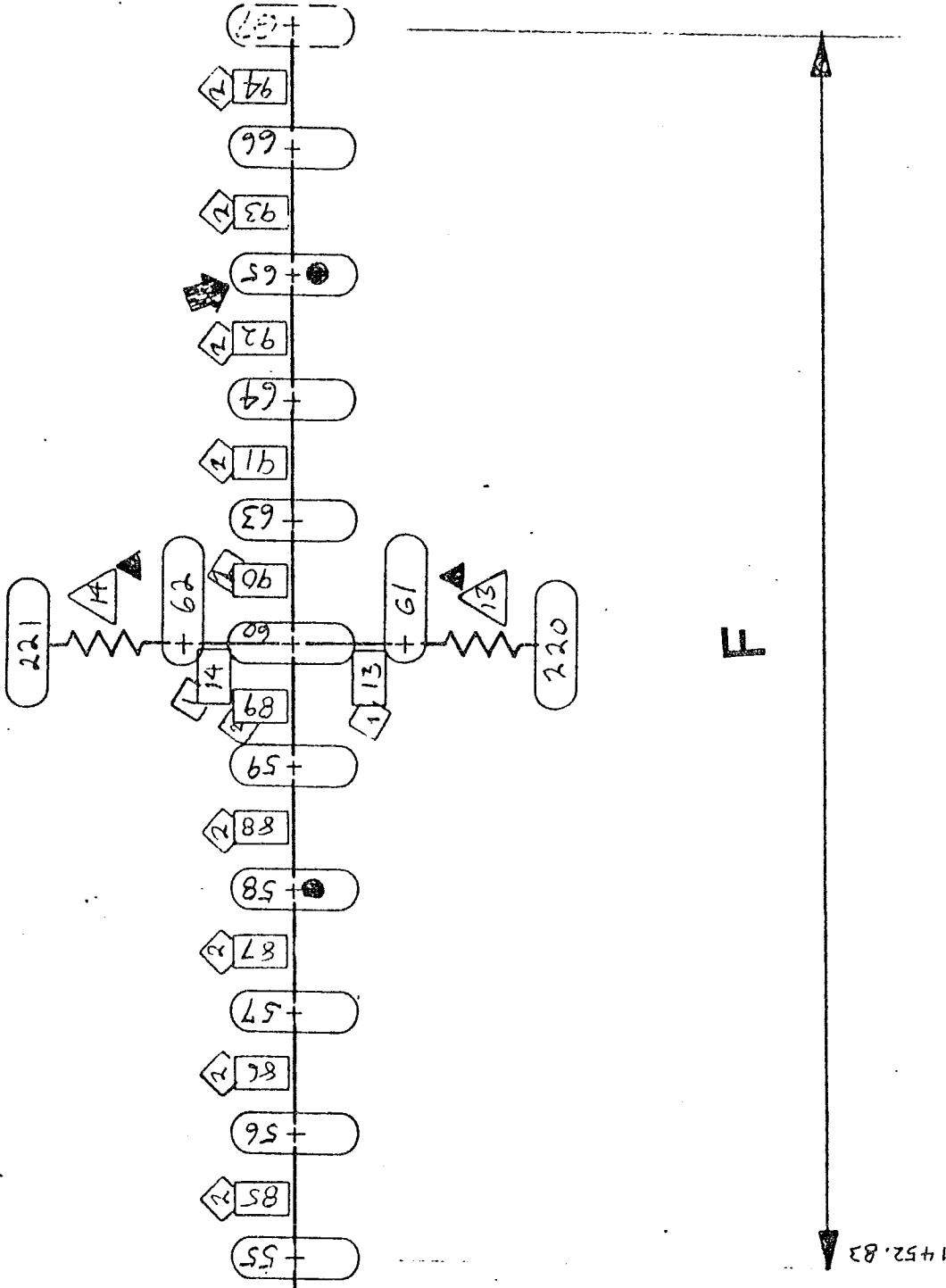


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NEW I-90

FIG. 11-1 SHT. 6/19

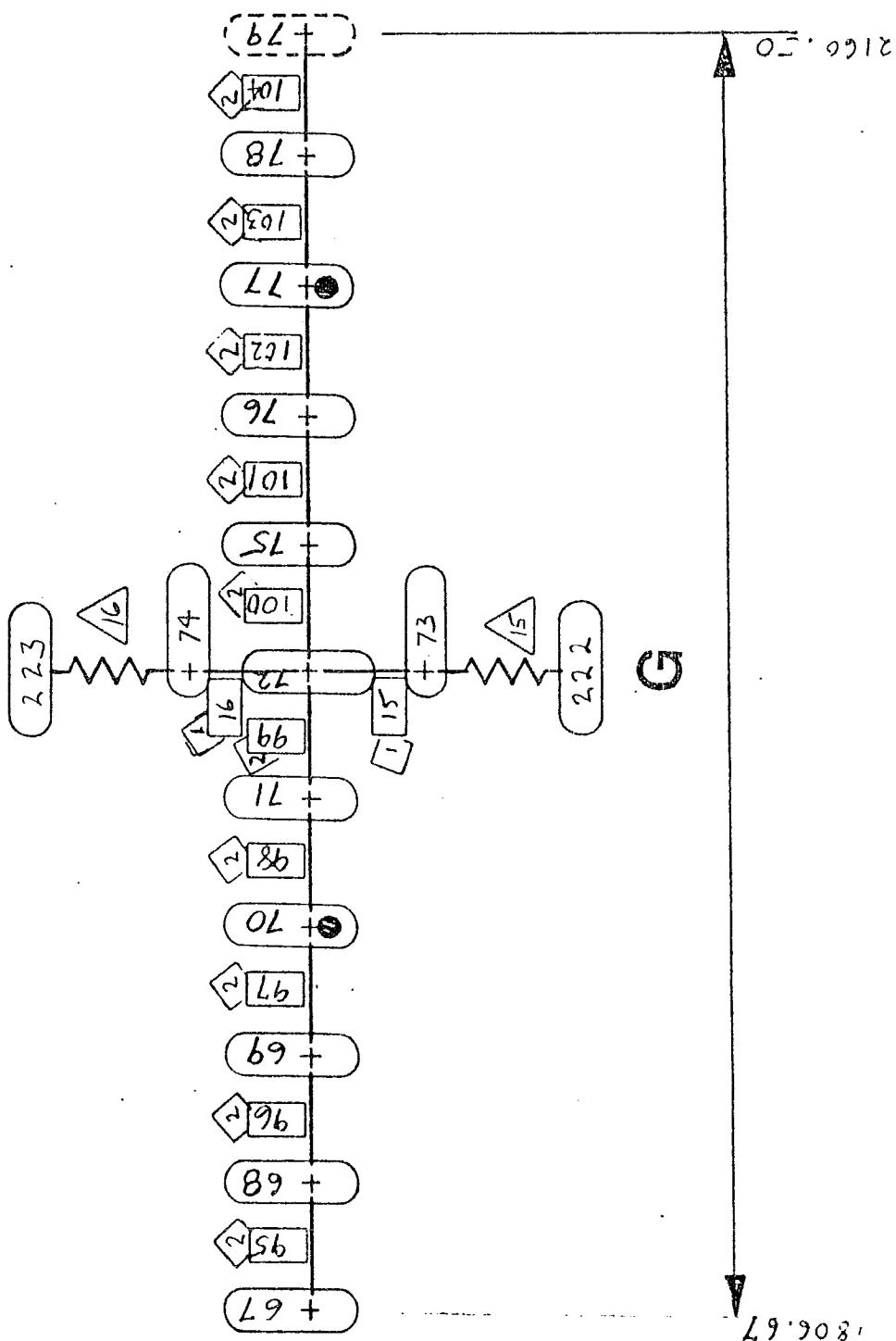


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NEW I-90

FIG. 11-1 SHT. 7/19

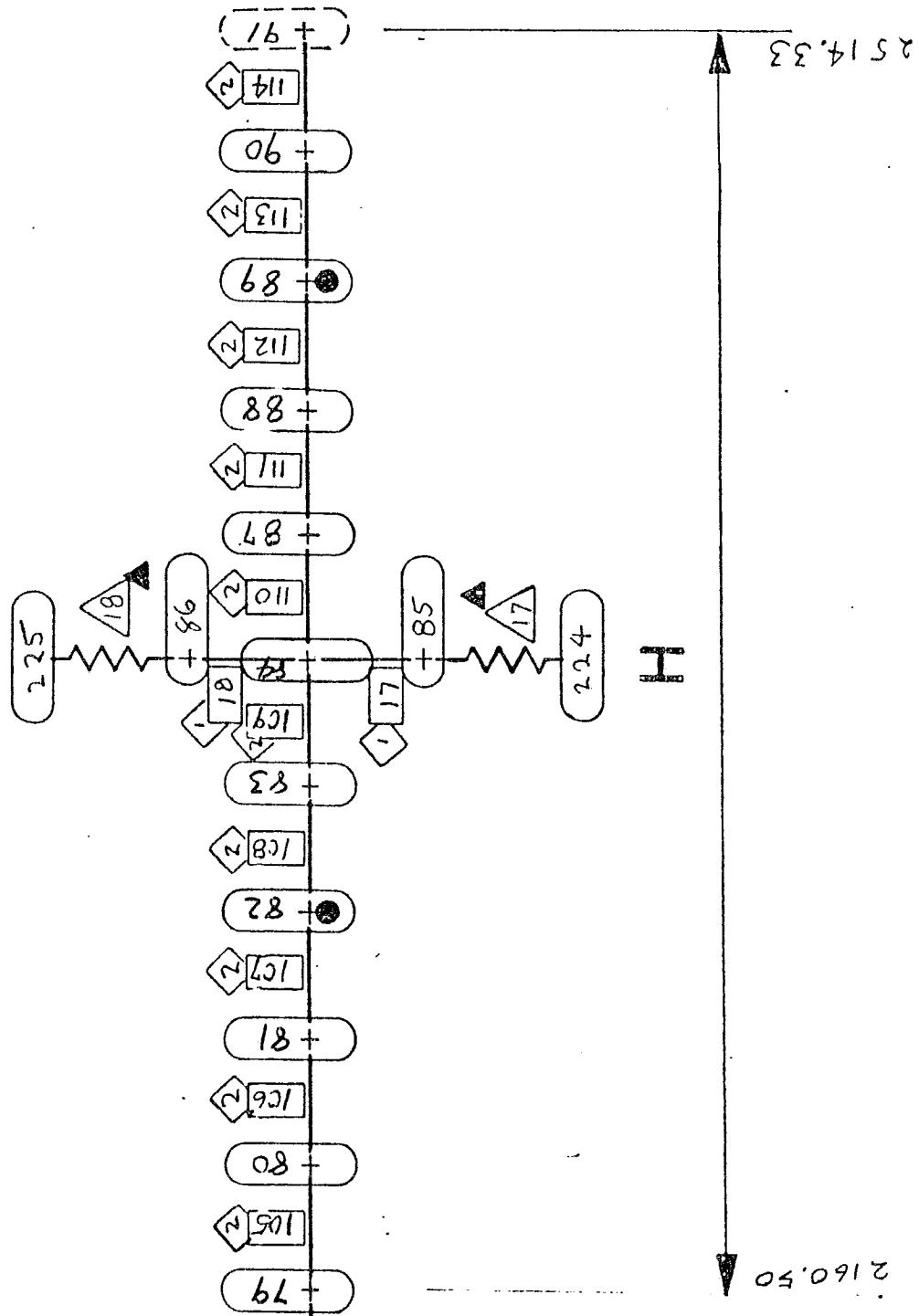


**kpff**

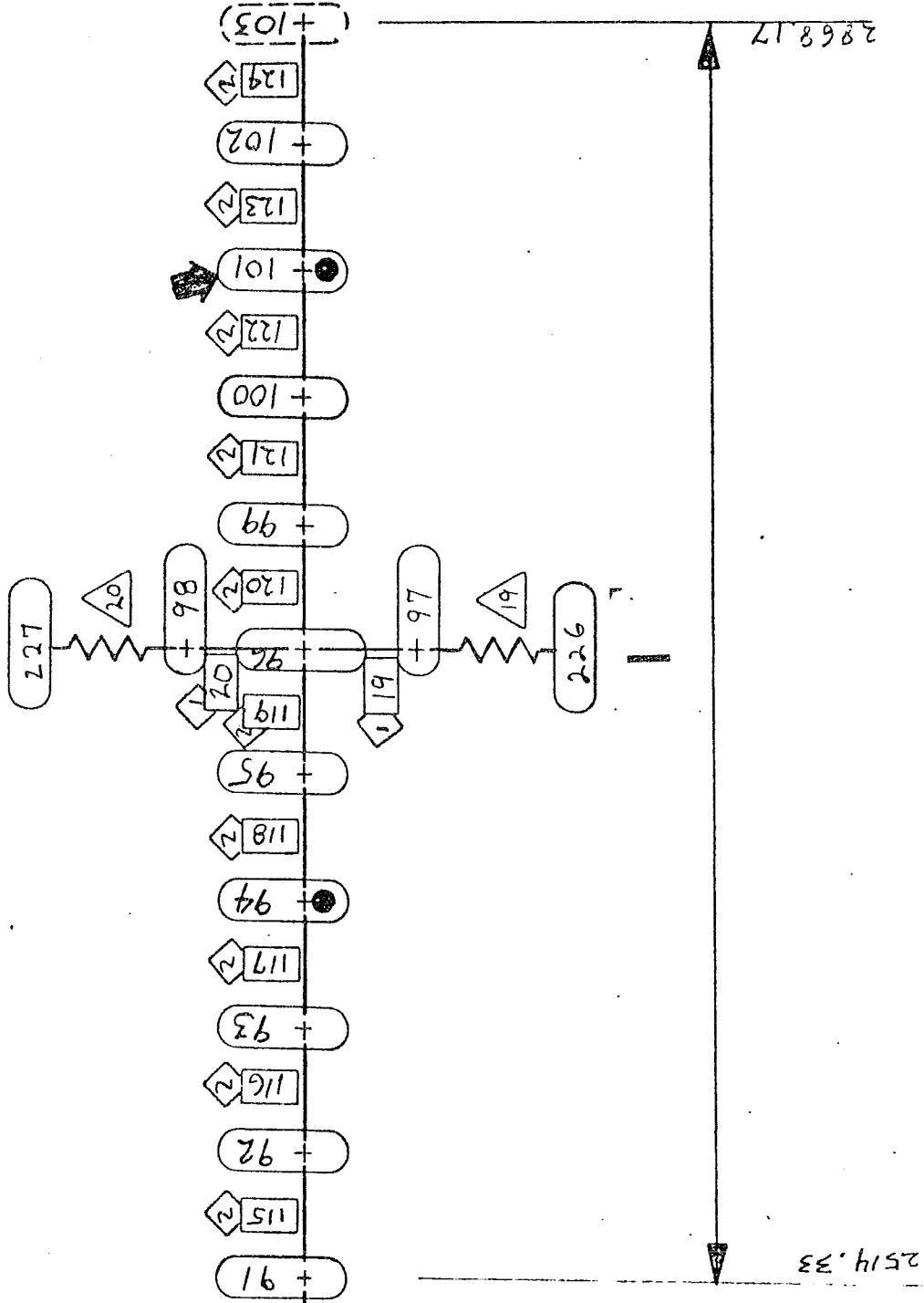
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NEW I-90

FIG. 11-1 SHT. 8/19



<b>kpff</b> consulting engineers seattle washington	<b>NEW I-90</b>	FIG. 11-1	SHT. 9/19
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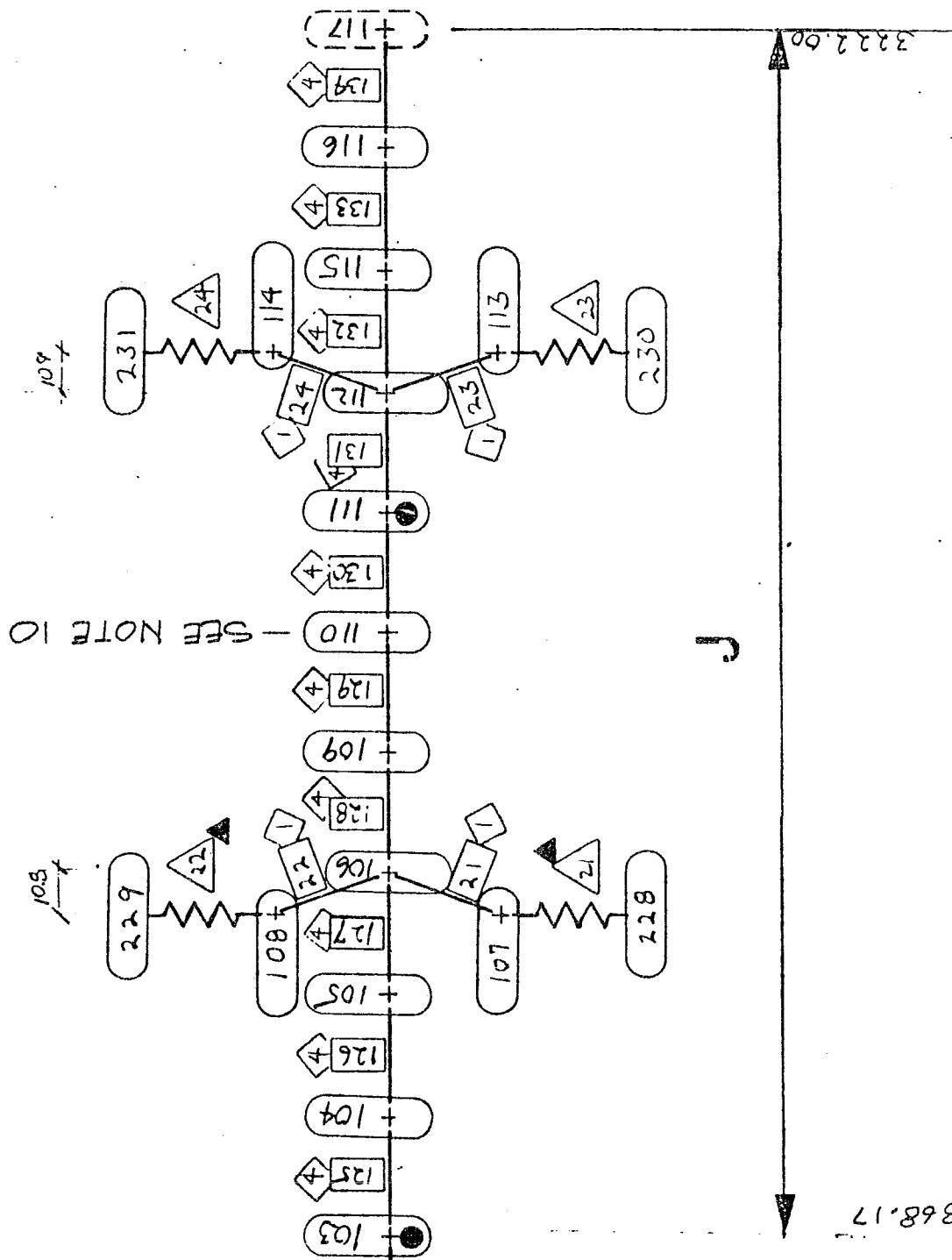


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NEW I-90

FIG. 11-1 SHT. 10/19



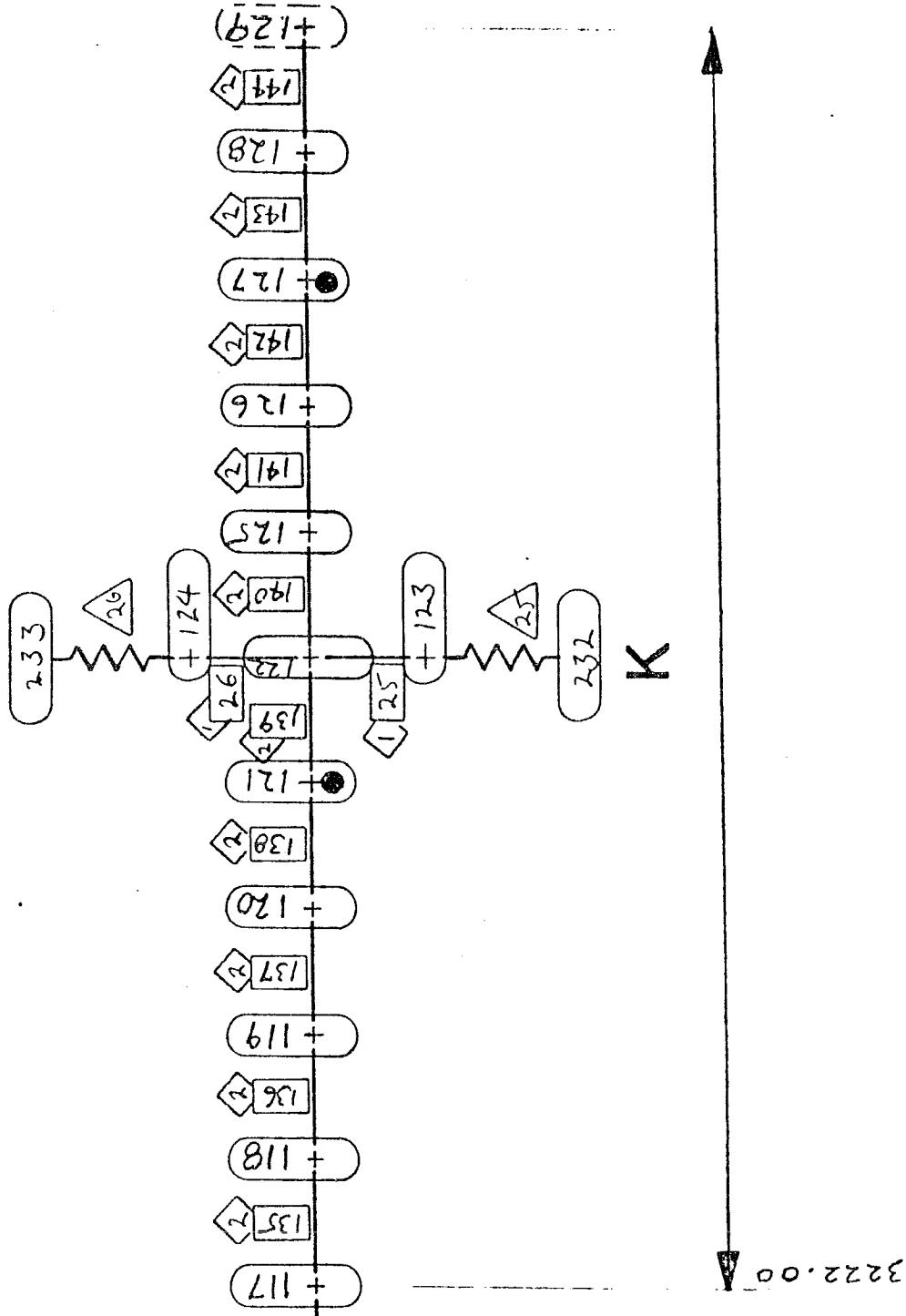
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NEW I-90

FIG. 11-1

SHT. 11/19



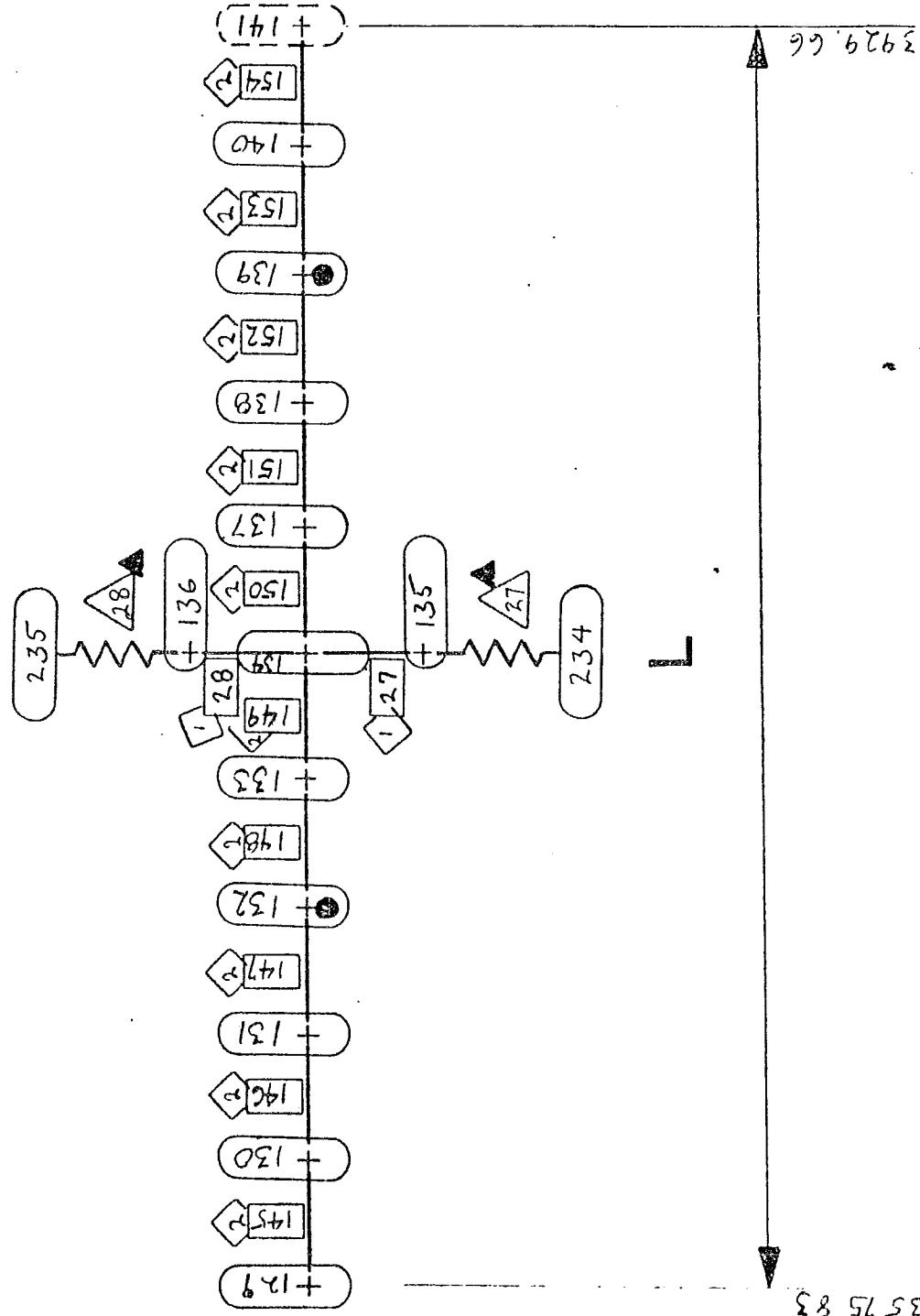
3222.00

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NEW I-90

FIG. 11-1 SHT. 12/19

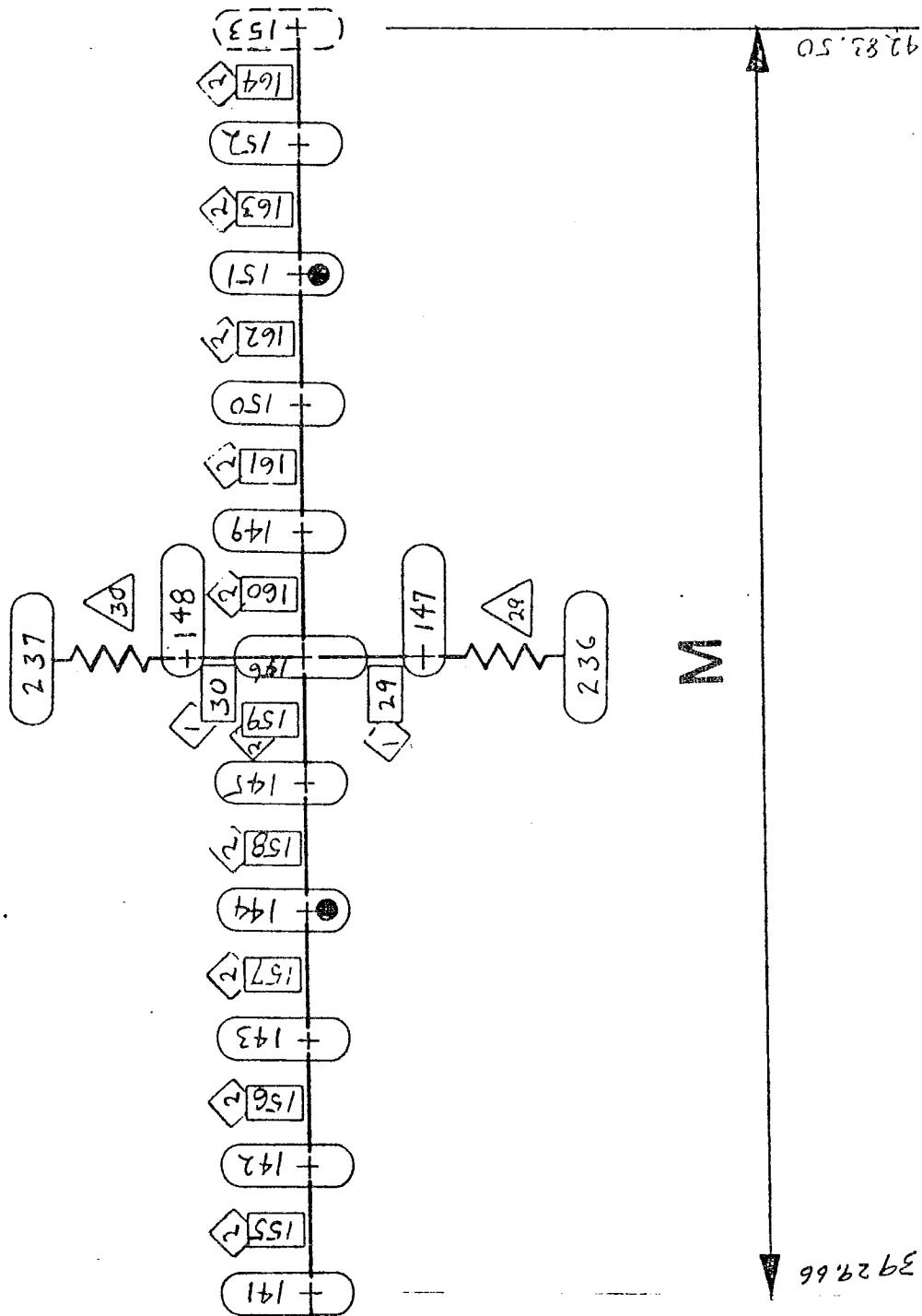


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NEW I-90

FIG. 11-1 SHT. 13/19

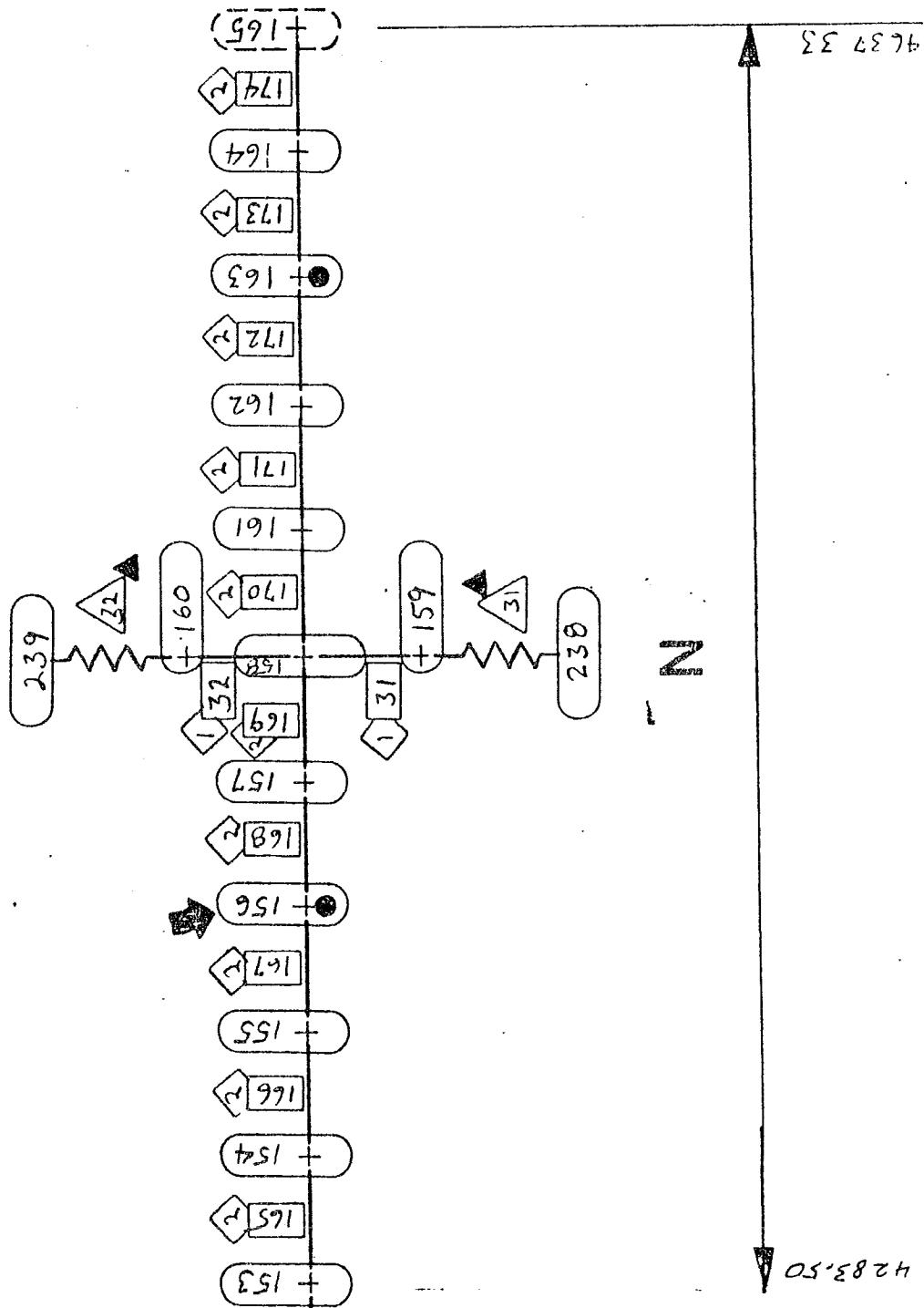


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NEW I-90

FIG. 11-1 SHT. 14/19

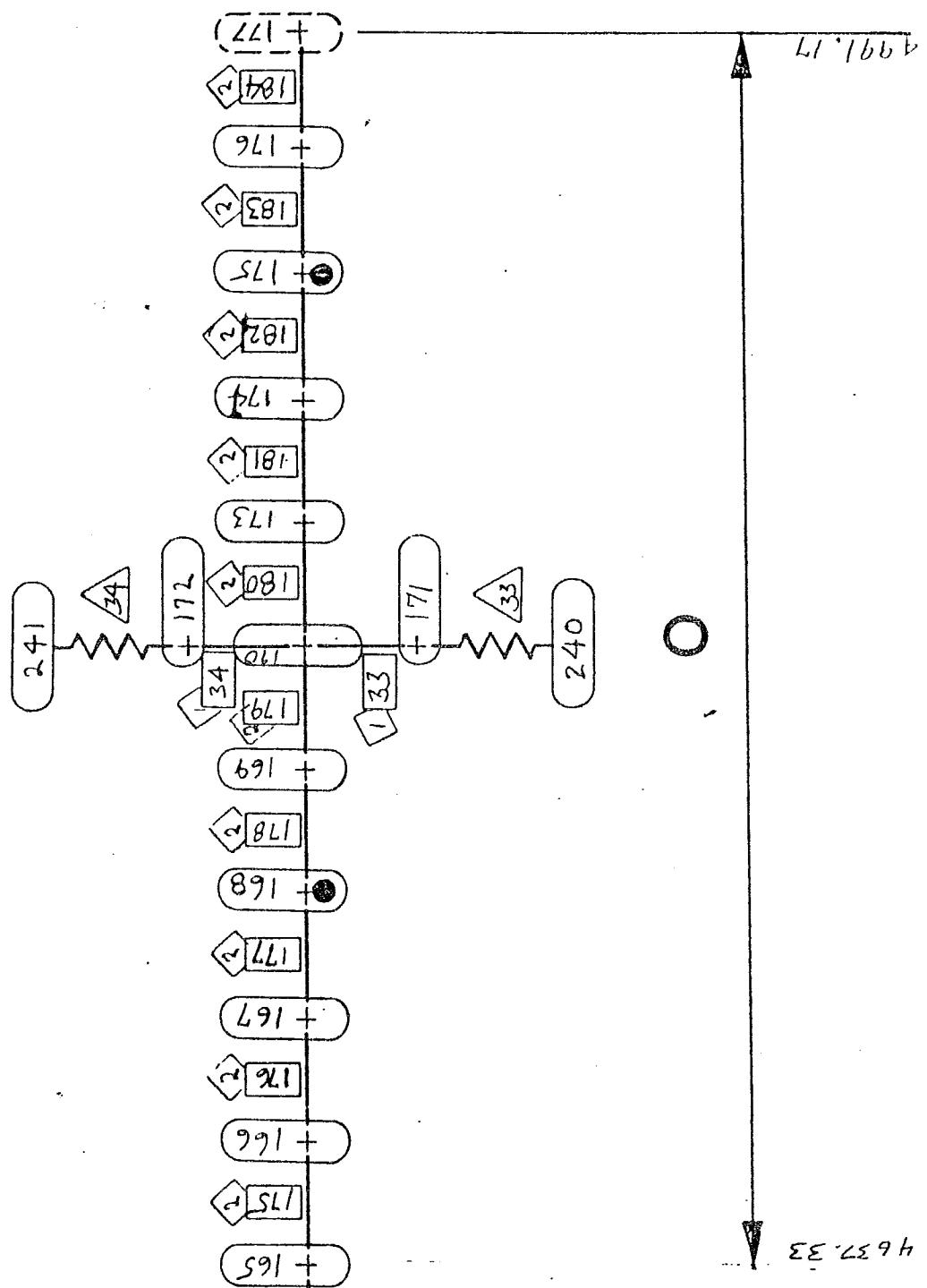


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NEW I-90

FIG. 11-1 SHT. 15/19

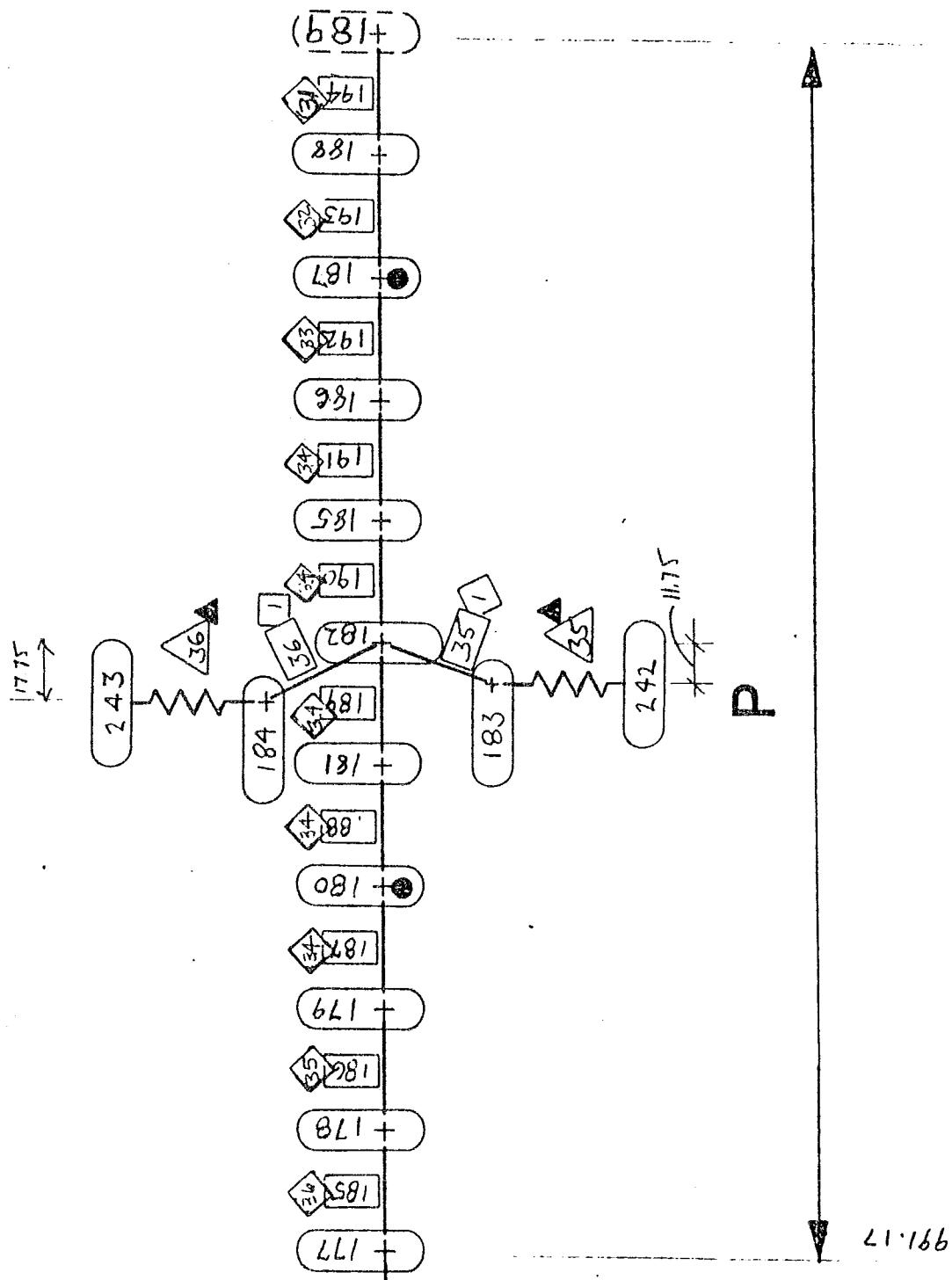


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NEW I-90

FIG. 11-1 SHT. 16/19



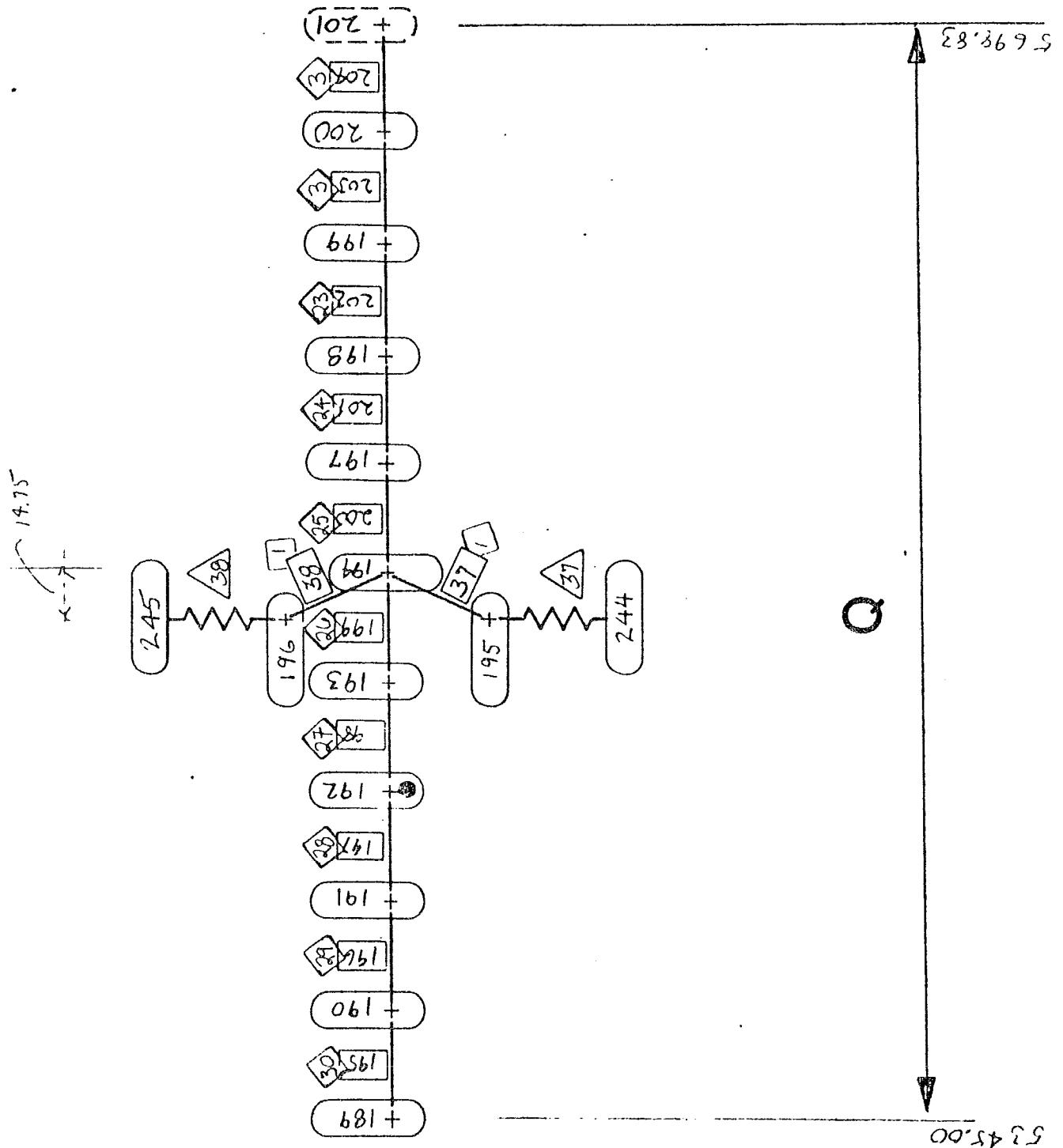
4991.17

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NEW I-90

FIG. 11-1 SHT. 17/19

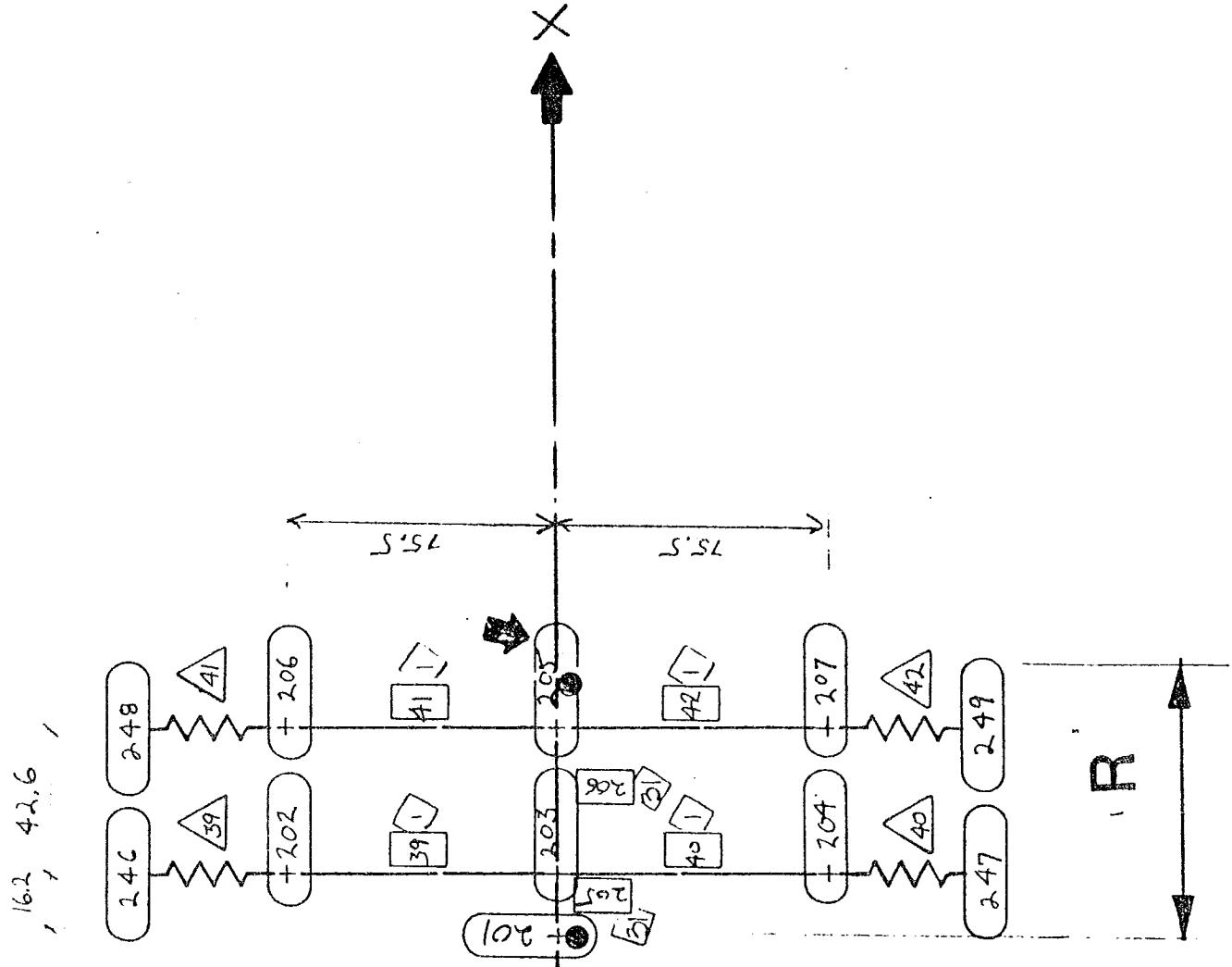


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NEW I-90

FIG. 11-1 SHT. 18/19



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NEW I-90

FIG. 11-1 SHT. 19/19

## 12. Structural Characteristics

### 12.1 Bridge Structure

The raised roadway was assumed not to contribute to the stiffness of the bridge due to its use of expansion joints. Similarly the spans at the ends supported by multi-directional pot bearings are assumed not to contribute to the stiffness of the floating bridge. The non-structural overlay is also modeled as not contributing stiffness. All of the above plus all the non-structural barriers, catwalks, ballast and miscellaneous items are modeled as contributing to the translational and rotational mass. Table 12-1 gives structural properties for each member, and Table 12-2 gives mass properties for each node, in the bridge model. Due to the similarities of many sections of the bridge, these are tabulated for a limited set of member and node type numbers, which are referenced on the node map, figure 11-1.

Hysteretic structural damping for small displacements in the post tensioned concrete is taken to be 2%.

### 12.2 Hydrostatic Restoring Forces

Table 12-3 presents the hydrostatic properties associated with each node in the analytical model. Only nodes accorded non-zero buoyant displacement are included. The convention adopted was to associate the buoyant displacement and other hydrostatic properties with nodes lying on the main longitudinal structural axis. The hydrostatic restoring forces shown are for heave roll and pitch.

### 12.3 Mooring Stiffnesses

Table 12-4 presents the linear mooring cable stiffnesses and direction cosines as used in the dynamic model of the new I-90 bridge. The cable stiffnesses presented are for a lake level 3 feet below design lake level. Cable stiffnesses are considerably greater for south mooring lines when compared to north mooring lines due to the differential behavior resulting from a steady 60 mph wind load from the south.

NO.	UNITS: KIPS, FEET	A R E A S			T E N S I O N			S H E A R - 3			A R O U T 2			A B C U T 3			E/G		
		A X I A L	S H E A R - 2	T E N S I O N	A R O U T 2	A B C U T 3	E/G	A R O U T 2	A B C U T 3	E/G	A R O U T 2	A B C U T 3	E/G	A R O U T 2	A B C U T 3	E/G			
1	120,000	50,000	65,500	25000,000	74270,000	12900,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
2	192,600	56,500	435,800	21847,000	157640,000	977,700	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
3	234,800	93,700	131,200	50230,000	145230,000	23348,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
4	205,000	52,600	131,200	26547,000	164330,000	11405,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
5	303,500	132,100	172,700	72450,000	228290,000	53464,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
6	297,400	126,000	172,700	76200,000	227800,000	47623,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
7	292,000	120,100	172,700	70000,000	219800,000	42800,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
8	286,000	114,500	172,700	65500,000	218000,000	38300,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
9	281,000	109,400	172,700	59150,000	211730,000	34443,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
10	276,000	103,900	172,700	53800,000	208200,000	31000,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
11	270,000	98,900	172,700	49200,000	204500,000	27700,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
12	266,500	94,000	172,700	44000,000	201110,000	24798,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
13	261,000	90,800	164,800	39350,000	196700,000	22700,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
14	257,000	89,000	164,800	38400,000	195000,000	21900,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
15	254,000	87,300	164,800	37100,000	193540,000	20199,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
16	252,000	86,000	164,800	36020,000	192200,000	19400,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
17	250,500	84,700	164,800	35050,000	191300,000	18700,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
18	250,000	83,700	164,800	34300,000	190500,000	18200,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
19	249,600	82,800	164,800	33110,000	190310,000	17931,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
20	244,000	78,500	164,800	30420,000	186900,000	16000,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
21	240,500	73,500	164,800	26890,000	183560,000	13670,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
22	235,300	68,700	164,800	23530,000	180330,000	11735,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
23	302,000	130,200	172,700	76296,000	226800,000	51000,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
24	294,000	122,900	172,700	73245,000	222000,000	45200,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
25	288,000	116,000	172,700	66400,000	217000,000	39400,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
26	282,500	109,500	172,700	59524,000	212500,000	34800,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
27	276,000	103,500	172,700	54150,000	208000,000	30800,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
28	270,000	97,800	172,700	49100,000	203700,000	27100,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
29	263,000	92,700	172,700	42250,000	199100,000	23620,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
30	256,000	87,800	172,700	37750,000	197380,000	20400,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
31	251,000	84,700	164,800	35190,000	191400,000	18700,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
32	250,000	83,300	164,800	34110,000	190300,000	18050,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
33	249,000	82,400	164,800	33350,000	189300,000	17600,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
34	248,300	81,800	164,800	32222,000	182110,000	17329,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
35	242,300	75,500	164,800	26250,000	184710,000	14534,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
36	236,300	59,400	164,800	23970,000	180300,000	12000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			
37	550,000	230,000	301,300	134010,000	341642,000	59384,000	648400,000	12000	12000	2,200	12000	12000	2,200	12000	12000	2,200			

TABLE 12-2

PROGRAM MASSGEN				ROTATIONAL MASSES				
NODE	NODE	FROM	TO	TRANSLATIONAL MASSES		0x	0y	0z
37	6	228.5	228.5	228.5	279629.0	46553.3	577103.5	
5	9	228.5	228.5	228.5	279629.0	46553.3	577103.5	
7	0	44.0	44.0	44.0	59830.0	5311.1	22159.7	
8	0	89.6	89.6	89.6	112067.0	17530.0	51326.4	
9	0	89.6	89.6	89.6	192615.0	17043.1	51326.4	
10	0	89.6	89.6	89.6	104836.0	13906.0	51326.4	
11	0	89.6	89.6	89.6	105662.0	16664.3	51326.4	
12	0	89.6	89.6	89.6	102689.0	16711.1	51326.4	
15	0	89.6	89.6	89.6	100022.0	16571.0	51326.4	
13	0	89.6	89.6	89.6	93708.0	16114.0	51326.4	
17	0	89.6	89.6	89.6	91856.0	15979.0	51326.4	
18	0	89.6	89.6	89.6	92746.7	15802.9	51326.4	
19	0	89.6	89.6	89.6	89943.0	15846.9	51326.4	
20	0	89.6	89.6	89.6	88255.0	15715.4	51326.4	
21	0	89.6	89.6	89.6	83556.0	15328.8	51326.4	
22	0	89.6	89.6	89.6	82656.0	15244.6	51326.4	
23	0	89.6	89.6	89.6	81261.0	15036.6	51326.4	
24	0	89.6	89.6	89.6	80113.0	14975.4	51326.4	
27	0	89.6	89.6	89.6	78857.0	14872.0	51326.4	
28	0	89.6	89.6	89.6	78727.0	14631.7	51326.4	
29	0	89.6	89.6	89.6	74757.0	14552.6	51326.4	
30	0	89.6	89.6	89.6	73790.0	14474.0	51326.4	
31	0	89.6	89.6	89.6	72992.0	14357.2	51326.4	
32	0	89.6	89.6	89.6	74313.0	14280.0	51326.4	
33	0	89.6	89.6	89.6	70370.0	14165.6	51326.4	
34	0	87.2	87.2	87.2	72019.0	14773.2	50383.2	
35	0	84.0	84.0	84.0	73029.0	15282.2	48567.9	
36	0	81.6	81.6	81.6	69373.0	14116.5	46724.0	
37	0	78.4	78.4	78.4	66041.0	13068.2	44261.2	
40	0	75.1	75.1	75.1	62630.0	12097.7	43056.0	
41	0	72.0	72.0	72.0	59540.0	11203.4	41271.1	
42	0	68.7	68.7	68.7	56763.0	10349.2	39384.7	
43	0	66.0	66.0	66.0	53973.0	9643.5	37860.7	
44	0	65.6	65.6	65.6	53325.0	9482.8	37569.4	
45	0	65.6	65.6	65.6	52263.0	9387.5	37569.4	
46	0	65.6	65.6	65.6	52541.0	9298.6	37569.4	
47	0	65.6	65.6	65.6	52296.0	9275.0	37569.4	
48	0	65.6	65.6	65.6	52053.0	9161.5	37569.4	
51	0	65.6	65.6	65.6	51202.0	9112.2	37569.4	
52	0	64.0	64.0	64.0	51314.0	8893.3	37160.0	
53	0	57.9	57.9	57.9	46842.0	7703.2	33155.7	
54	0	52.1	52.1	52.1	42800.0	6740.2	29945.5	
55	0	47.0	47.0	47.0	41541.0	5923.6	26944.6	
56	60	46.3	46.3	46.3	38125.0	5832.6	26512.5	
63	72	46.3	46.3	46.3	38125.0	5832.6	26512.5	
75	94	46.3	46.3	46.3	38125.0	5832.6	26512.5	
87	96	46.3	46.3	46.3	38125.0	5832.6	26512.5	
22	103	46.3	46.3	46.3	38125.0	5832.6	26512.5	
104	106	55.2	55.2	55.2	43657.0	7232.5	31643.0	
107	112	55.2	55.2	55.2	43657.0	7232.5	31643.0	
115	117	55.2	55.2	55.2	43657.0	7232.5	31643.0	
118	122	46.3	46.3	46.3	38125.0	5832.6	26512.5	
125	134	46.3	46.3	46.3	38125.0	5832.6	26512.5	
137	146	46.3	46.3	46.3	38125.0	5832.6	26512.5	
149	150	46.3	46.3	46.3	38125.0	5832.6	26512.5	
161	170	46.3	46.3	46.3	38125.0	5832.6	26512.5	
173	177	46.3	46.3	46.3	38125.0	5832.6	26512.5	
178	0	54.0	54.0	54.0	44961.0	7049.0	30731.1	
179	0	61.7	61.7	61.7	48349.0	8342.5	35342.6	
180	182	65.6	65.6	65.6	51417.0	9023.9	37569.4	
185	186	65.6	65.6	65.6	51417.0	9023.9	37569.4	
187	0	65.6	65.6	65.6	51417.0	9023.9	37569.4	
188	0	65.6	65.6	65.6	51801.0	9157.0	37569.4	
189	0	65.6	65.6	65.6	52082.0	9245.5	37569.4	
190	0	68.7	68.7	68.7	54307.0	9014.0	39384.7	
191	0	71.9	71.9	71.9	57202.0	10765.0	41217.0	
192	0	75.1	75.1	75.1	60419.0	11655.7	43030.0	
193	0	78.4	78.4	78.4	63569.0	12587.2	44901.7	
194	0	81.6	81.6	81.6	66957.0	13695.2	46734.0	
197	0	84.7	84.7	84.7	70657.0	14805.9	48550.1	
198	0	87.9	87.9	87.9	74937.0	16216.4	50303.2	
199	0	89.6	89.6	89.6	97311.0	15542.1	51326.4	
200	0	89.6	89.6	89.6	77450.0	14552.6	51326.4	
201	0	44.0	44.0	44.0	40997.0	3772.8	22159.7	
203	0	202.5	202.5	202.5	160465.0	35331.1	455835.3	
205	0	202.5	202.5	202.5	160465.0	35331.1	455835.3	

NODAL MASSES (Kilo Slugs & Kilo Slugs Ft<sup>2</sup>)

TABLE 12-3  
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NEW I-90 BRIDGE  
GEOMETRIC AND HYDROSTATIC PROPERTIES

N	TYPE	L (WL)	B (WL)	T	V	DISPL	X-LOC	Z-B	X-CF	HYDROSTATIC COEFFICIENTS				
										dFz/dz	dMx/d0x	dMy/d0y	dFz/d0y	dMy/dz
(FT)	(FT)	(FT)	(FT)	(FT^3)	(KIPS)	(FT)	(FT)	(FT)	(FT)	(K/FT)	(K-FT)	(K-FT)	(KIPS)	(KIPS)
1	1	37.5	170	18.5	117937	7359.3	-21.33	-9.25	2.58	397.8	889961.	-21456.	1026.32	1026.32
3	1	37.5	170	18.5	117937	7359.3	21.33	-9.25	-2.58	397.8	889961.	-21456.	1026.32	1026.32
7	2	17.69	75	17.42	23111.	1442.19	37.5	-8.708	8.845	82.789	26243.0	-10405.	732.270	732.270
5	3	35.38	75	17.42	46223.	2884.37	72.88	-8.708	0	165.57	52486.1	-7856.8	0	0
9	3	35.38	75	17.42	46223.	2884.37	108.3	-8.708	0	165.57	52486.1	-7856.8	0	0
10	3	35.38	75	17.42	46223.	2884.37	143.7	-8.708	0	165.57	52486.1	-7856.8	0	0
11	3	35.38	75	17.42	46223.	2884.37	179	-8.708	0	165.57	52486.1	-7856.8	0	0
12	3	35.38	75	17.42	46223.	2884.37	214.4	-8.708	0	165.57	52486.1	-7856.8	0	0
15	3	35.38	75	17.42	46223.	2884.37	249.8	-8.708	0	165.57	52486.1	-7856.8	0	0
16	3	35.38	75	17.42	46223.	2884.37	285.2	-8.708	0	165.57	52486.1	-7856.8	0	0
17	3	35.38	75	17.42	46223.	2884.37	320.6	-8.708	0	165.57	52486.1	-7856.8	0	0
18	3	35.38	75	17.42	46223.	2884.37	355.9	-8.708	0	165.57	52486.1	-7856.8	0	0
19	3	35.38	75	17.42	46223.	2884.37	391.3	-8.708	0	165.57	52486.1	-7856.8	0	0
20	3	35.38	75	17.42	46223.	2884.37	426.7	-8.708	0	165.57	52486.1	-7856.8	0	0
21	3	35.38	75	17.42	46223.	2884.37	462.1	-8.708	0	165.57	52486.1	-7856.8	0	0
22	3	35.38	75	17.42	46223.	2884.37	497.5	-8.708	0	165.57	52486.1	-7856.8	0	0
23	3	35.38	75	17.42	46223.	2884.37	532.9	-8.708	0	165.57	52486.1	-7856.8	0	0
24	3	35.38	75	17.42	46223.	2884.37	568.3	-8.708	0	165.57	52486.1	-7856.8	0	0
27	3	35.38	75	17.42	46223.	2884.37	603.6	-8.708	0	165.57	52486.1	-7856.8	0	0
28	3	35.38	75	17.42	46223.	2884.37	639	-8.708	0	165.57	52486.1	-7856.8	0	0
29	3	35.38	75	17.42	46223.	2884.37	674.4	-8.708	0	165.57	52486.1	-7856.8	0	0
30	3	35.38	75	17.42	46223.	2884.37	709.8	-8.708	0	165.57	52486.1	-7856.8	0	0
31	3	35.38	75	17.42	46223.	2884.37	745.2	-8.708	0	165.57	52486.1	-7856.8	0	0
32	3	35.38	75	17.42	46223.	2884.37	780.5	-8.708	0	165.57	52486.1	-7856.8	0	0
33	3	35.38	75	17.42	46223.	2884.37	815.9	-8.708	0	165.57	52486.1	-7856.8	0	0
34	4	35.38	75	17.1	45374.	2831.39	851.3	-8.551	0	165.57	53409.3	-6933.7	0	0
35	5	35.38	75	16.48	43729.	2728.73	886.7	-8.24	0	165.57	55130.1	-5212.9	0	0
36	6	35.38	75	15.86	42084.	2626.07	922.1	-7.929	0	165.57	56787.4	-3555.5	0	0
39	7	35.38	75	15.24	40439.	2523.41	957.5	-7.618	0	165.57	58381.4	-1961.6	0	0
40	8	35.38	75	14.61	38767.	2419.10	992.8	-7.306	0	165.57	59945.7	-397.28	0	0
41	9	35.38	75	13.99	37122.	2316.44	1028.2	-6.995	0	165.57	61411.3	1068.30	0	0
42	10	35.38	75	13.37	35477.	2213.78	1063.6	-6.684	0	165.57	62813.5	2470.46	0	0
43	11	35.38	75	12.83	34044.	2124.37	1099	-6.414	0	165.57	63984.9	3641.85	0	0
44	12	35.38	75	12.75	33832.	2111.12	1134.4	-6.375	0	165.57	64156.4	3813.40	0	0
45	12	35.38	75	12.75	33832.	2111.12	1169.8	-6.375	0	165.57	64156.4	3813.40	0	0
46	12	35.38	75	12.75	33832.	2111.12	1205.2	-6.375	0	165.57	64156.4	3813.40	0	0
47	12	35.38	75	12.75	33832.	2111.12	1240.5	-6.375	0	165.57	64156.4	3813.40	0	0
48	12	35.38	75	12.75	33832.	2111.12	1275.9	-6.375	0	165.57	64156.4	3813.40	0	0
51	12	35.38	75	12.75	33832.	2111.12	1311.3	-6.375	0	165.57	64156.4	3813.40	0	0

TABLE 12-3 (cont'd)

N	TYPE	L (WL) (FT)	B (WL) (FT)	T (FT)	V (FT^3)	DISPL (KIPS)	X-LOC (FT)	Z-B (FT)	X-CF (FT)	HYDROSTATIC COEFFICIENTS				
										dFz/dz (K/FT)	dMx/d0x (K-FT)	dMy/d0y (K-FT)	dFz/d0y (KIPS)	dMy/dz (KIPS)
52	13	35.38	75	12.61	33460.	2087.94	1346.7	-6.305	0	165.57	64450.3	4107.33	0	0
53	14	35.38	75	11.25	29851.	1862.75	1382.1	-5.626	0	165.57	67138.7	6795.67	0	0
54	15	35.38	75	10.13	26879.	1677.30	1417.5	-5.063	0	165.57	69115.9	8772.89	0	0
55	16	35.38	75	9.141	24255.	1513.55	1452.83	-4.57	0	165.57	70698.4	10353.3	0	0
56	17	35.38	75	9	23881.	1490.20	1488.2	-4.5	0	165.57	70908.9	10565.8	0	0
57	17	35.38	75	9	23881.	1490.20	1523.6	-4.5	0	165.57	70908.9	10565.8	0	0
58	17	35.38	75	9	23881.	1490.20	1559	-4.5	0	165.57	70908.9	10565.8	0	0
59	17	35.38	75	9	23881.	1490.20	1594.4	-4.5	0	165.57	70908.9	10565.8	0	0
60	17	35.38	75	9	23881.	1490.20	1629.8	-4.5	0	165.57	70908.9	10565.8	0	0
63	17	35.38	75	9	23881.	1490.20	1665.1	-4.5	0	165.57	70908.9	10565.8	0	0
64	17	35.38	75	9	23881.	1490.20	1700.5	-4.5	0	165.57	70908.9	10565.8	0	0
65	17	35.38	75	9	23881.	1490.20	1735.9	-4.5	0	165.57	70908.9	10565.8	0	0
66	17	35.38	75	9	23881.	1490.20	1771.3	-4.5	0	165.57	70908.9	10565.8	0	0
67	17	35.38	75	9	23881.	1490.20	1806.67	-4.5	0	165.57	70908.9	10565.8	0	0
68	17	35.38	75	9	23881.	1490.20	1842.1	-4.5	0	165.57	70908.9	10565.8	0	0
69	17	35.38	75	9	23881.	1490.20	1877.4	-4.5	0	165.57	70908.9	10565.8	0	0
70	17	35.38	75	9	23881.	1490.20	1912.8	-4.5	0	165.57	70908.9	10565.8	0	0
71	17	35.38	75	9	23881.	1490.20	1948.2	-4.5	0	165.57	70908.9	10565.8	0	0
72	17	35.38	75	9	23881.	1490.20	1983.6	-4.5	0	165.57	70908.9	10565.8	0	0
75	17	35.38	75	9	23881.	1490.20	2018.9	-4.5	0	165.57	70908.9	10565.8	0	0
76	17	35.38	75	9	23881.	1490.20	2054.4	-4.5	0	165.57	70908.9	10565.8	0	0
77	17	35.38	75	9	23881.	1490.20	2089.7	-4.5	0	165.57	70908.9	10565.8	0	0
78	17	35.38	75	9	23881.	1490.20	2125.2	-4.5	0	165.57	70908.9	10565.8	0	0
79	17	35.38	75	9	23881.	1490.20	2160.5	-4.5	0	165.57	70908.9	10565.8	0	0
80	17	35.38	75	9	23881.	1490.20	2195.9	-4.5	0	165.57	70908.9	10565.8	0	0
81	17	35.38	75	9	23881.	1490.20	2231.3	-4.5	0	165.57	70908.9	10565.8	0	0
82	17	35.38	75	9	23881.	1490.20	2266.7	-4.5	0	165.57	70908.9	10565.8	0	0
83	17	35.38	75	9	23881.	1490.20	2302	-4.5	0	165.57	70908.9	10565.8	0	0
84	17	35.38	75	9	23881.	1490.20	2337.4	-4.5	0	165.57	70908.9	10565.8	0	0
87	17	35.38	75	9	23881.	1490.20	2372.8	-4.5	0	165.57	70908.9	10565.8	0	0
88	17	35.38	75	9	23881.	1490.20	2408.2	-4.5	0	165.57	70908.9	10565.8	0	0
89	17	35.38	75	9	23881.	1490.20	2443.6	-4.5	0	165.57	70908.9	10565.8	0	0
90	17	35.38	75	9	23881.	1490.20	2478.9	-4.5	0	165.57	70908.9	10565.8	0	0
91	17	35.38	75	9	23881.	1490.20	2514.33	-4.5	0	165.57	70908.9	10565.8	0	0
92	17	35.38	75	9	23881.	1490.20	2549.7	-4.5	0	165.57	70908.9	10565.8	0	0
93	17	35.38	75	9	23881.	1490.20	2585.1	-4.5	0	165.57	70908.9	10565.8	0	0
94	17	35.38	75	9	23881.	1490.20	2620.5	-4.5	0	165.57	70908.9	10565.8	0	0
95	17	35.38	75	9	23881.	1490.20	2655.8	-4.5	0	165.57	70908.9	10565.8	0	0
96	17	35.38	75	9	23881.	1490.20	2691.3	-4.5	0	165.57	70908.9	10565.8	0	0
99	17	35.38	75	9	23881.	1490.20	2726.6	-4.5	0	165.57	70908.9	10565.8	0	0
100	17	35.38	75	9	23881.	1490.20	2762	-4.5	0	165.57	70908.9	10565.8	0	0
101	17	35.38	75	9	23881.	1490.20	2797.4	-4.5	0	165.57	70908.9	10565.8	0	0
102	17	35.38	75	9	23881.	1490.20	2832.8	-4.5	0	165.57	70908.9	10565.8	0	0
103	18	35.38	75	9.387	24908.	1554.28	2868.17	-4.694	0	165.57	70320.6	9977.56	0	0

TABLE 12-3 cont'd)

## HYDROSTATIC COEFFICIENTS

N	TYPE	L (WL)	B (WL)	T	V	DISPL	X-LOC	Z-B	X-CF	dFz/dz	dMx/d0x	dMy/d0y	dFz/d0y	dMy/dz
		(FT)	(FT)	(FT)	(FT^3)	(KIPS)	(FT)	(FT)	(FT)	(K/FT)	(K-FT)	(K-FT)	(KIPS)	(KIPS)
104	19	35.38	75	10.74	28498.	1778.31	2903.5	-5.37	0	165.57	68065.3	7722.28	0	0
105	19	35.38	75	10.75	28525.	1779.96	2938.9	-5.375	0	165.57	68047.5	7704.49	0	0
106	19	35.38	75	10.75	28525.	1779.96	2974.3	-5.375	0	165.57	68047.5	7704.49	0	0
107	19	35.38	75	10.75	28525.	1779.96	3009.7	-5.375	0	165.57	68047.5	7704.49	0	0
110	19	35.38	75	10.75	28525.	1779.96	3045.1	-5.375	0	165.57	68047.5	7704.49	0	0
111	19	35.38	75	10.75	28525.	1779.96	3080.5	-5.375	0	165.57	68047.5	7704.49	0	0
112	19	35.38	75	10.75	28525.	1779.96	3115.9	-5.375	0	165.57	68047.5	7704.49	0	0
115	19	35.38	75	10.75	28525.	1779.96	3151.2	-5.375	0	165.57	68047.5	7704.49	0	0
116	19	35.38	75	10.74	28498.	1778.31	3186.6	-5.37	0	165.57	68065.3	7722.28	0	0
117	18	35.38	75	9.387	24908.	1554.28	3222	-4.694	0	165.57	70320.6	9977.56	0	0
118	17	35.38	75	9	23881.	1490.20	3257.4	-4.5	0	165.57	70908.9	10565.8	0	0
119	17	35.38	75	9	23881.	1490.20	3292.7	-4.5	0	165.57	70908.9	10565.8	0	0
120	17	35.38	75	9	23881.	1490.20	3328.1	-4.5	0	165.57	70908.9	10565.8	0	0
121	17	35.38	75	9	23881.	1490.20	3363.53	-4.5	0	165.57	70908.9	10565.8	0	0
122	17	35.38	75	9	23881.	1490.20	3398.9	-4.5	0	165.57	70908.9	10565.8	0	0
125	17	35.38	75	9	23881.	1490.20	3434.3	-4.5	0	165.57	70908.9	10565.8	0	0
126	17	35.38	75	9	23881.	1490.20	3469.7	-4.5	0	165.57	70908.9	10565.8	0	0
127	17	35.38	75	9	23881.	1490.20	3505.1	-4.5	0	165.57	70908.9	10565.8	0	0
128	17	35.38	75	9	23881.	1490.20	3540.5	-4.5	0	165.57	70908.9	10565.8	0	0
129	17	35.38	75	9	23881.	1490.20	3577.83	-4.5	0	165.57	70908.9	10565.8	0	0
130	17	35.38	75	9	23881.	1490.20	3611.2	-4.5	0	165.57	70908.9	10565.8	0	0
131	17	35.38	75	9	23881.	1490.20	3646.6	-4.5	0	165.57	70908.9	10565.8	0	0
132	17	35.38	75	9	23881.	1490.20	3681.9	-4.5	0	165.57	70908.9	10565.8	0	0
133	17	35.38	75	9	23881.	1490.20	3717.4	-4.5	0	165.57	70908.9	10565.8	0	0
134	17	35.38	75	9	23881.	1490.20	3752.8	-4.5	0	165.57	70908.9	10565.8	0	0
137	17	35.38	75	9	23881.	1490.20	3788.1	-4.5	0	165.57	70908.9	10565.8	0	0
138	17	35.38	75	9	23881.	1490.20	3823.5	-4.5	0	165.57	70908.9	10565.8	0	0
139	17	35.38	75	9	23881.	1490.20	3858.9	-4.5	0	165.57	70908.9	10565.8	0	0
140	17	35.38	75	9	23881.	1490.20	3894.3	-4.5	0	165.57	70908.9	10565.8	0	0
141	17	35.38	75	9	23881.	1490.20	3929.66	-4.5	0	165.57	70908.9	10565.8	0	0
142	17	35.38	75	9	23881.	1490.20	3965.1	-4.5	0	165.57	70908.9	10565.8	0	0
143	17	35.38	75	9	23881.	1490.20	4000.4	-4.5	0	165.57	70908.9	10565.8	0	0
144	17	35.38	75	9	23881.	1490.20	4035.8	-4.5	0	165.57	70908.9	10565.8	0	0
145	17	35.38	75	9	23881.	1490.20	4071.2	-4.5	0	165.57	70908.9	10565.8	0	0
146	17	35.38	75	9	23881.	1490.20	4106.6	-4.5	0	165.57	70908.9	10565.8	0	0
149	17	35.38	75	9	23881.	1490.20	4142	-4.5	0	165.57	70908.9	10565.8	0	0
150	17	35.38	75	9	23881.	1490.20	4177.4	-4.5	0	165.57	70908.9	10565.8	0	0
151	17	35.38	75	9	23881.	1490.20	4212.7	-4.5	0	165.57	70908.9	10565.8	0	0
152	17	35.38	75	9	23881.	1490.20	4248.1	-4.5	0	165.57	70908.9	10565.8	0	0
153	17	35.38	75	9	23881.	1490.20	4283.5	-4.5	0	165.57	70908.9	10565.8	0	0
154	17	35.38	75	9	23881.	1490.20	4318.9	-4.5	0	165.57	70908.9	10565.8	0	0
155	17	35.38	75	9	23881.	1490.20	4354.3	-4.5	0	165.57	70908.9	10565.8	0	0

TABLE 12-3 (cont'd)

N	TYPE	L (WL) (FT)	B (WL) (FT)	T (FT)	V (FT^3)	DISPL (KIPS)	X-LOC (FT)	Z-B (FT)	X-CF (FT)	HYDROSTATIC COEFFICIENTS				
										dFz/dz (K/FT)	dMx/d0x (K-FT)	dMy/d0y (K-FT)	dFz/d0y (KIPS)	dMy/dz (KIPS)
156	17	35.38	75	9	23881.	1490.20	4389.7	-4.5	0	165.57	70908.9	10565.8	0	0
157	17	35.38	75	9	23881.	1490.20	4425	-4.5	0	165.57	70908.9	10565.8	0	0
158	17	35.38	75	9	23881.	1490.20	4460.4	-4.5	0	165.57	70908.9	10565.8	0	0
159	17	35.38	75	9	23881.	1490.20	4495.8	-4.5	0	165.57	70908.9	10565.8	0	0
160	17	35.38	75	9	23881.	1490.20	4531.2	-4.5	0	165.57	70908.9	10565.8	0	0
161	17	35.38	75	9	23881.	1490.20	4566.6	-4.5	0	165.57	70908.9	10565.8	0	0
162	17	35.38	75	9	23881.	1490.20	4601.9	-4.5	0	165.57	70908.9	10565.8	0	0
163	17	35.38	75	9	23881.	1490.20	4637.33	-4.5	0	165.57	70908.9	10565.8	0	0
164	17	35.38	75	9	23881.	1490.20	4672.7	-4.5	0	165.57	70908.9	10565.8	0	0
165	17	35.38	75	9	23881.	1490.20	4708.1	-4.5	0	165.57	70908.9	10565.8	0	0
166	17	35.38	75	9	23881.	1490.20	4743.5	-4.5	0	165.57	70908.9	10565.8	0	0
167	17	35.38	75	9	23881.	1490.20	4778.9	-4.5	0	165.57	70908.9	10565.8	0	0
168	17	35.38	75	9	23881.	1490.20	4814.3	-4.5	0	165.57	70908.9	10565.8	0	0
169	17	35.38	75	9	23881.	1490.20	4849.6	-4.5	0	165.57	70908.9	10565.8	0	0
170	17	35.38	75	9	23881.	1490.20	4885	-4.5	0	165.57	70908.9	10565.8	0	0
171	17	35.38	75	9	23881.	1490.20	4920.4	-4.5	0	165.57	70908.9	10565.8	0	0
172	17	35.38	75	9	23881.	1490.20	4955.9	-4.5	0	165.57	70908.9	10565.8	0	0
173	17	35.38	75	9	24255.	1513.55	4991.17	-4.57	0	165.57	70696.4	10353.3	0	0
174	20	35.38	75	10.5	27861.	1738.57	5026.6	-5.252	0	165.57	68490.8	8147.78	0	0
175	21	35.38	75	12.004	31852.	1987.60	5061.9	-6.414	0	165.57	66504.1	6161.11	0	0
176	12	35.38	75	12.75	33832.	2111.12	5097.3	-6.375	0	165.57	64156.4	3813.40	0	0
177	12	35.38	75	12.75	33832.	2111.12	5132.7	-6.375	0	165.57	64156.4	3813.40	0	0
178	12	35.38	75	12.75	33832.	2111.12	5168.1	-6.375	0	165.57	64156.4	3813.40	0	0
179	12	35.38	75	12.75	33832.	2111.12	5203.5	-6.375	0	165.57	64156.4	3813.40	0	0
180	12	35.38	75	12.75	33832.	2111.12	5238.9	-6.375	0	165.57	64156.4	3813.40	0	0
181	12	35.38	75	12.75	33832.	2111.12	5274.2	-6.375	0	165.57	64156.4	3813.40	0	0
182	12	35.38	75	12.75	33832.	2111.12	5309.6	-6.375	0	165.57	64156.4	3813.40	0	0
183	11	35.38	75	12.83	34044.	2124.37	5345	-6.414	0	165.57	63984.9	3641.85	0	0
184	10	35.38	75	13.37	35477.	2213.78	5380.4	-6.686	0	165.57	62817.9	2474.89	0	0
185	9	35.38	75	13.99	37122.	2316.44	5415.8	-7	0	165.57	61422.9	1079.89	0	0
186	8	35.38	75	14.61	38767.	2419.10	5451.2	-7.308	0	165.57	59950.6	-392.45	0	0
187	7	35.38	75	15.24	40439.	2523.41	5486.5	-7.618	0	165.57	58381.4	-1961.6	0	0
188	6	35.38	75	15.86	42084.	2626.07	5521.9	-7.929	0	165.57	56787.4	-3555.5	0	0
189	5	35.38	75	16.48	43729.	2728.73	5557.3	-8.24	0	165.57	55130.1	-5212.9	0	0
190	4	35.38	75	17.1	45374.	2831.39	5592.7	-8.551	0	165.57	53409.3	-6933.7	0	0
191	3	35.38	75	17.42	46223.	2884.37	5628.1	-8.708	0	165.57	52486.1	-7856.8	0	0
192	3	35.38	75	17.42	46223.	2884.37	5663.45	-8.708	0	165.57	52486.1	-7856.8	0	0
193	2	17.49	75	17.42	23111.	1442.18	5698.83	-8.708	8.845	82.789	26243.0	-10405.	732.270	732.270
194	22	37.5	160	17.42	104520	6522.04	5715	-8.708	2.58	374.4	741899.	-12945.	965.952	965.952
195	22	37.5	160	17.42	104520	6522.04	5757.66	-8.708	-2.58	374.4	741899.	-12945.	965.952	965.952

TABLE 12-4

ANCHOR I.D.	NODE #	SPRING CONSTANT	DIRECTION COSINES		
			X-DIR	Y-DIR	Z-DIR
A-NW	1	7529	0.0000	.8875	-.4609
A-SW	2	95263	0.0000	-.9347	-.3555
A-NE	4	9346	0.0000	.8923	-.4514
A-SE	6	115551	0.0000	-.9437	-.3309
B-S	13	91029	0.0000	-.9304	-.3665
B-N	14	17875	0.0000	.9079	-.4193
C-S	25	81110	0.0000	-.9303	-.3667
C-N	26	18849	0.0000	.9095	-.4157
D-S	37	78300	0.0000	-.9266	-.3761
D-N	38	18849	0.0000	.9095	-.4157
E-S	49	80168	0.0000	-.9285	-.3714
E-N	50	18866	0.0000	.9089	-.4170
F-S	61	77906	0.0000	-.9236	-.3833
F-N	62	17853	0.0000	.9038	-.4280
G-S	73	77906	0.0000	-.9236	-.3833
G-N	74	19407	0.0000	.9065	-.4223
H-S	85	77906	0.0000	-.9236	-.3833
H-N	86	19773	0.0000	.9065	-.4222
I-S	97	77906	0.0000	-.9236	-.3833
I-N	98	17296	0.0000	.9105	-.4135
J-S	110	76997	0.0000	-.9205	-.3908
J-N	110	18668	-.0004	.9306	-.3660
L-1S	107	55478	-.9274	-.2333	-.2924
L-2S	107	53123	-.9092	-.2459	-.3361
L-3S	107	51944	-.8979	-.2595	-.3556
L-4S	113	58539	.9058	-.2621	-.3329
L-5S	113	60001	.9163	-.2480	-.3143
L-6S	113	60378	.9264	-.2332	-.2956
L-1N	108	39116	-.9052	.2266	-.3595
L-2N	108	35845	-.8922	.2401	-.3824
L-3N	108	31618	-.8790	.2529	-.4042
L-4N	114	35494	.8884	.2888	-.3569
L-5N	114	28390	.8877	.2393	-.3934
L-6N	114	34789	.9027	.2262	-.3660
K-S	123	79016	-.0000	-.9222	-.3868
K-N	124	10181	-.0000	.8992	-.4376
L-S	135	79651	0.0000	-.9229	-.3850
L-N	136	11960	0.0000	.9095	-.4158
M-S	147	78290	0.0000	-.9200	-.3920
M-N	148	14875	0.0000	.9339	-.3576
N-S	159	121101	0.0000	-.9555	-.2950
N-N	160	18855	0.0000	.9665	-.2567
O-S	171	223347	0.0000	-.9777	-.2099
O-N	172	13437	0.0000	.9646	-.2636
P-S	183	157980	0.0000	-.9584	-.2854
P-N	184	15207	0.0000	.9629	-.2698
Q-S	195	151854	0.0000	-.9572	-.2894
Q-N	196	9628	0.0000	.9311	-.3647
R-NW	202	13690	0.0000	.9444	-.3289
R-SW	204	154808	0.0000	-.9664	-.2572
R-NE	206	9739	0.0000	.9321	-.3622
R-SE	207	153577	0.0000	-.9588	-.2841

## 13. Hydrodynamic Characteristics

### 13.1 Hydrodynamic Added Mass and Damping

A total of twenty-two unique underwater geometries are required to describe the new I-90 floating bridge. Hydrodynamic type numbers are given in the second column of Table 12-3.

Dimensional added mass and damping was determined for each unique underwater form at each of the thirty (30) discrete frequencies, considered in the dynamic analysis.

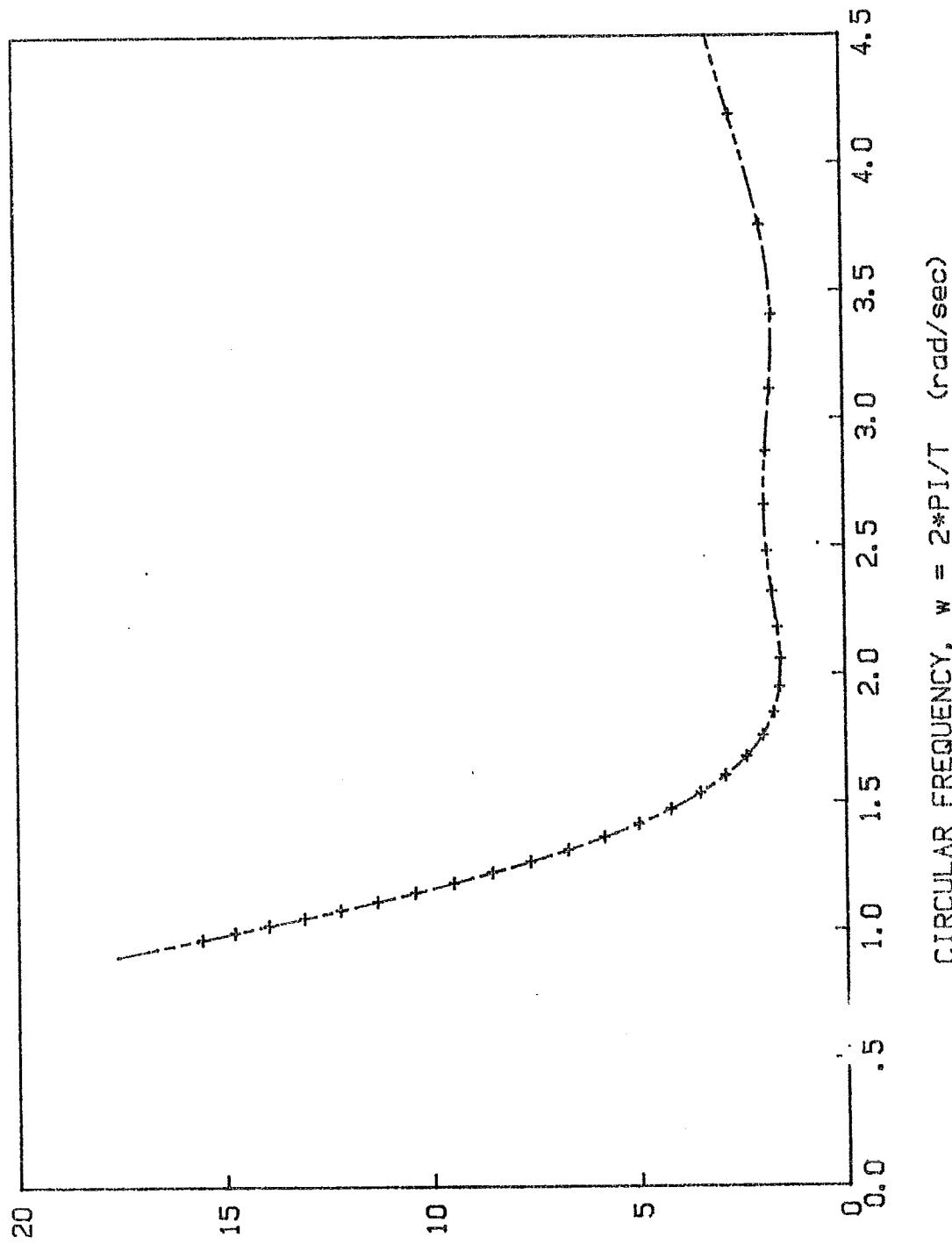
Figures 13-1 through 13-4 show the variation with frequency of the hydrodynamic added mass for a typical bridge segment in the respective modes of sway, heave, roll and sway-roll cross inertia. Similarly figures 13-5 through 13-8 show the variation with frequency of hydrodynamic damping for a typical bridge segment in the same sequence of respective response modes.

Table 13-9 and presents the full added mass and damping matrices for this same typical bridge segment at a frequency of  $\omega = 1.5377$  rad/sec.

### 13.2 Wave Forces and Moments

The complex-valued wave forcing function vectors for the applied wave forces and moments at each node were computed for the twenty-two unique underwater geometries. Wave forcing functions were all normalized by a unit amplitude wave at each of the thirty (30) discrete frequencies considered in the dynamic analysis. Figures 13-11 through 13-13 show the variation with frequency of the normalized wave forcing functions for, respectively, lateral force, vertical force, and roll moment.

NEW I-90 BRIDGE



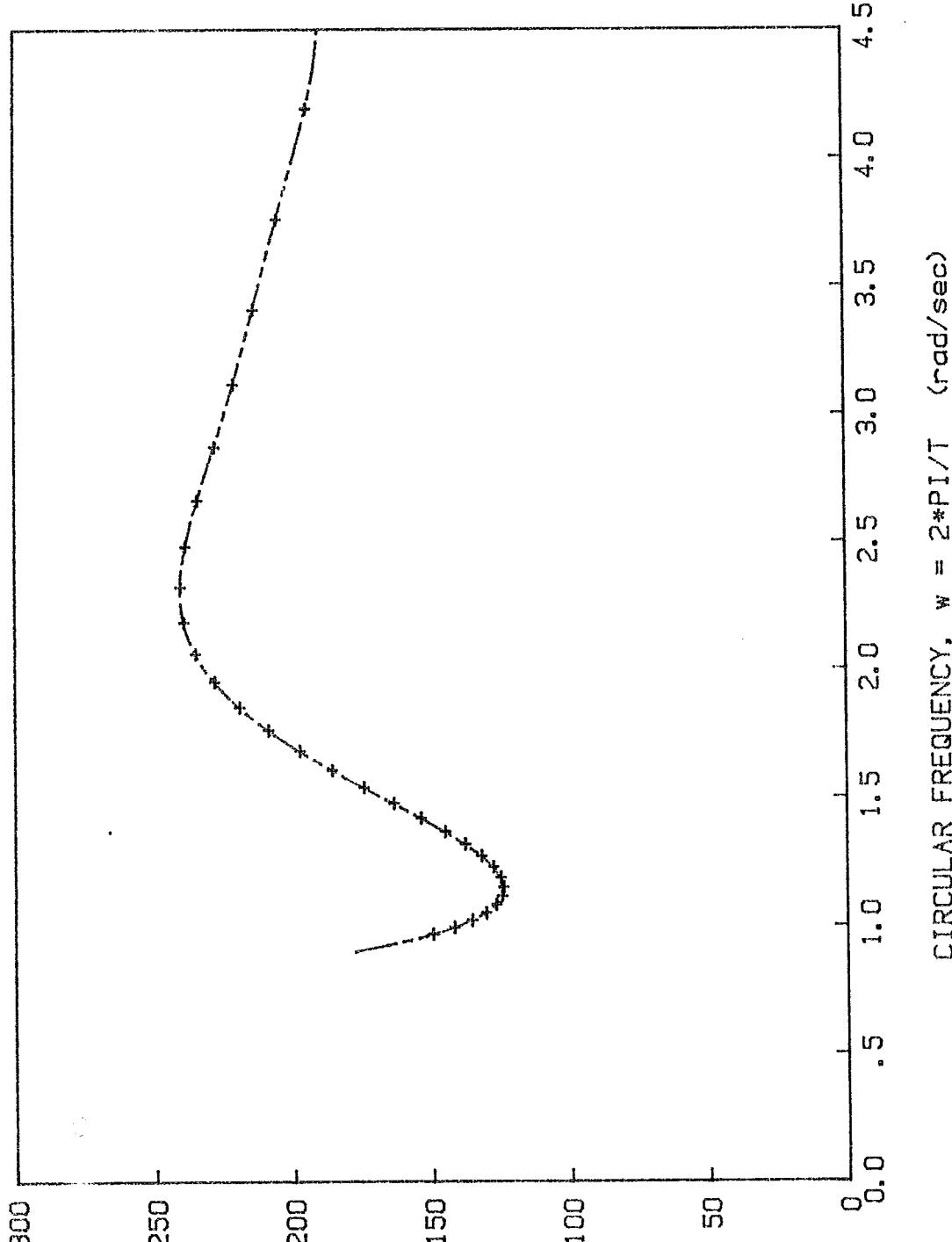
SWAY ADDED MASS, kip-sec<sup>2</sup>/ft

FIGURE 19-1

THE GUSTAVSON ASSOCIATES, INC.  
1963

ENR 1000

NEW T-SO BRIDGE



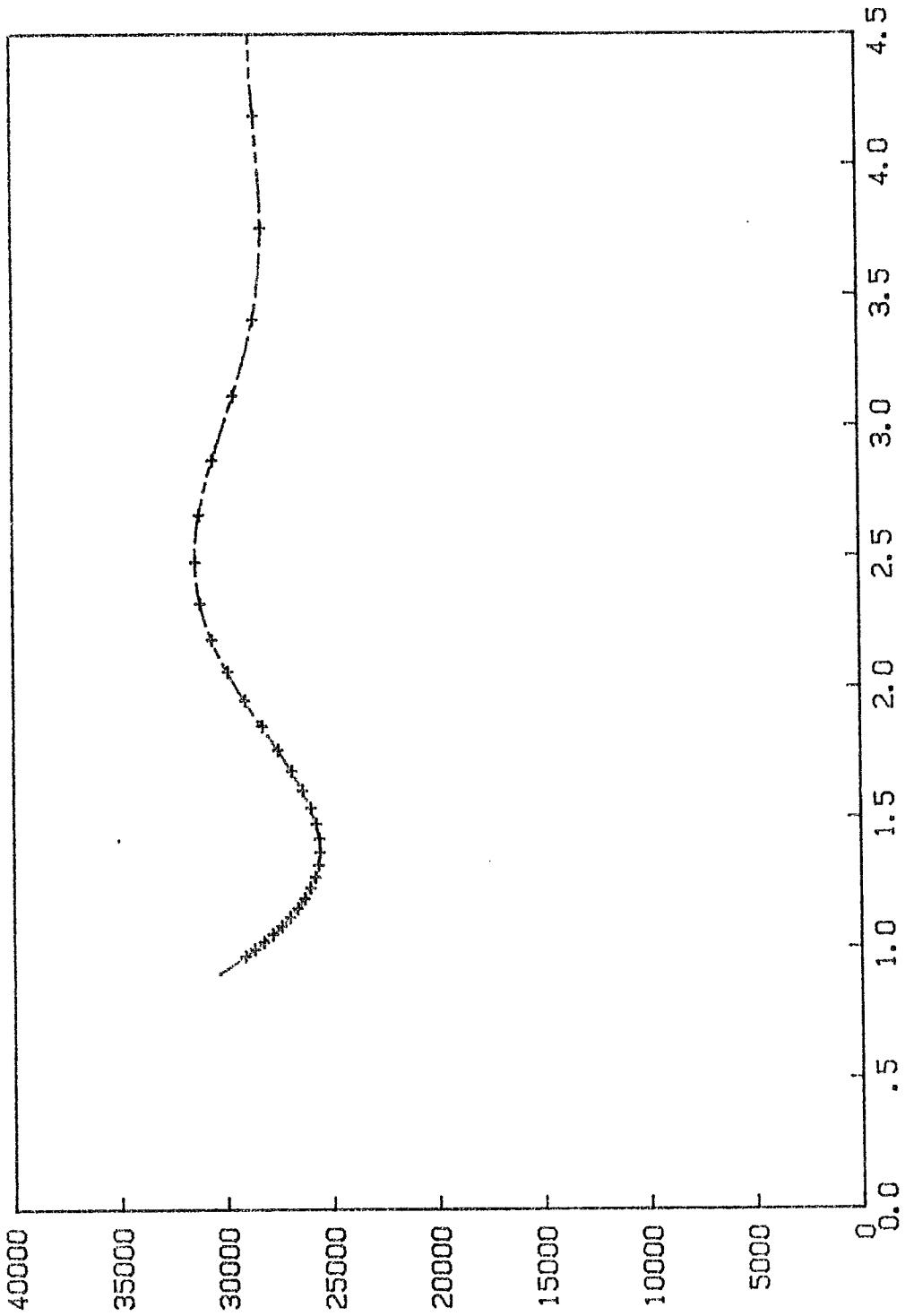
HEAVY ADDED MASS, kip-sec<sup>2</sup>/ft

FIGURE 13-2

THE GLOSTEN ASSOCIATES, inc.  
19 MAY 1983

FIGURE 13-2

FIGURE 13-2



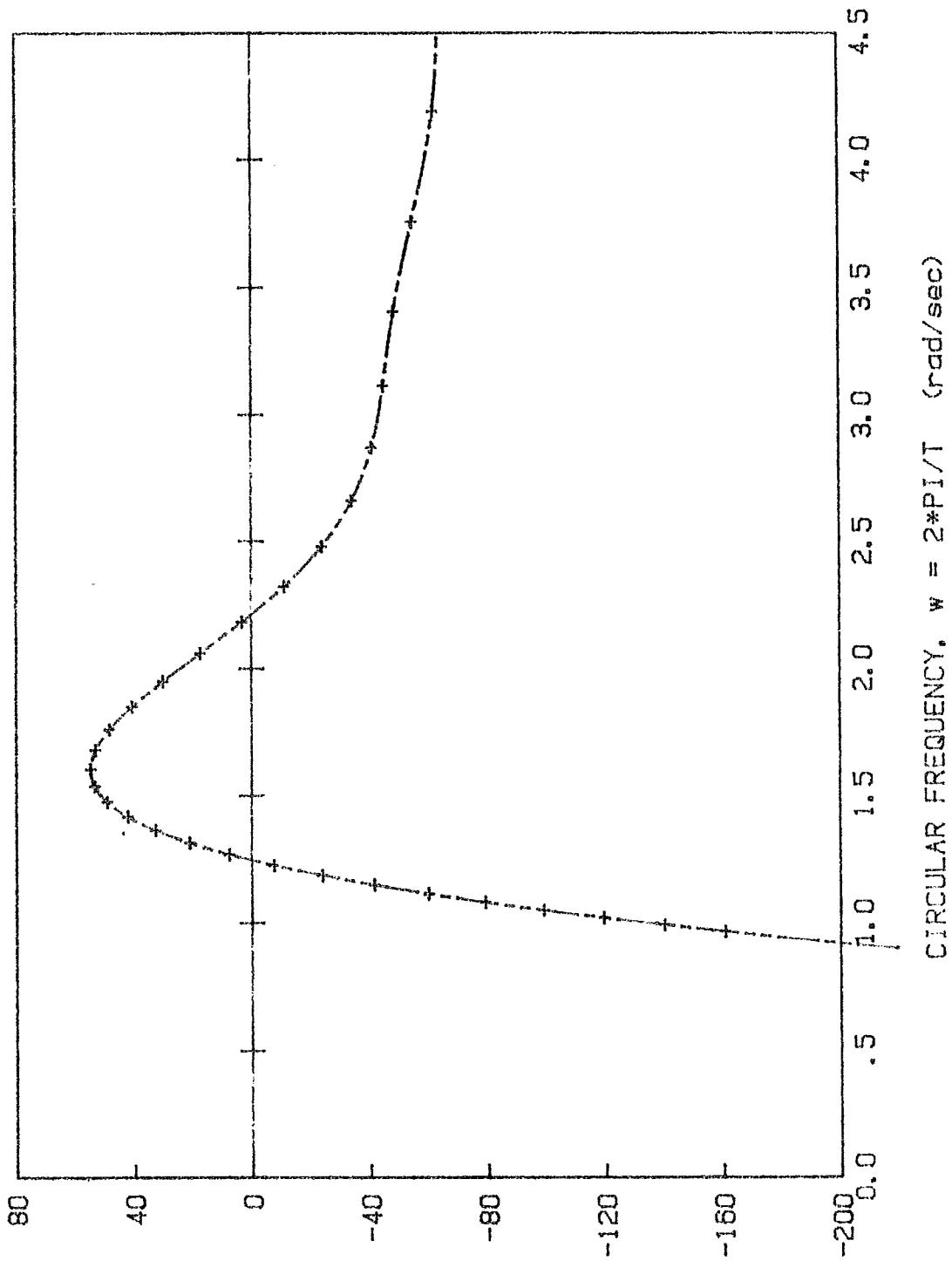
ROLL ADDED INERTIA, kip-sec<sup>2</sup>-ft

FIGURE 13-3

THE GLOSTEN ASSOCIATES, INC.  
IS MAY 1963

FIGURE 13-3

NEW I-90 BRIDGE



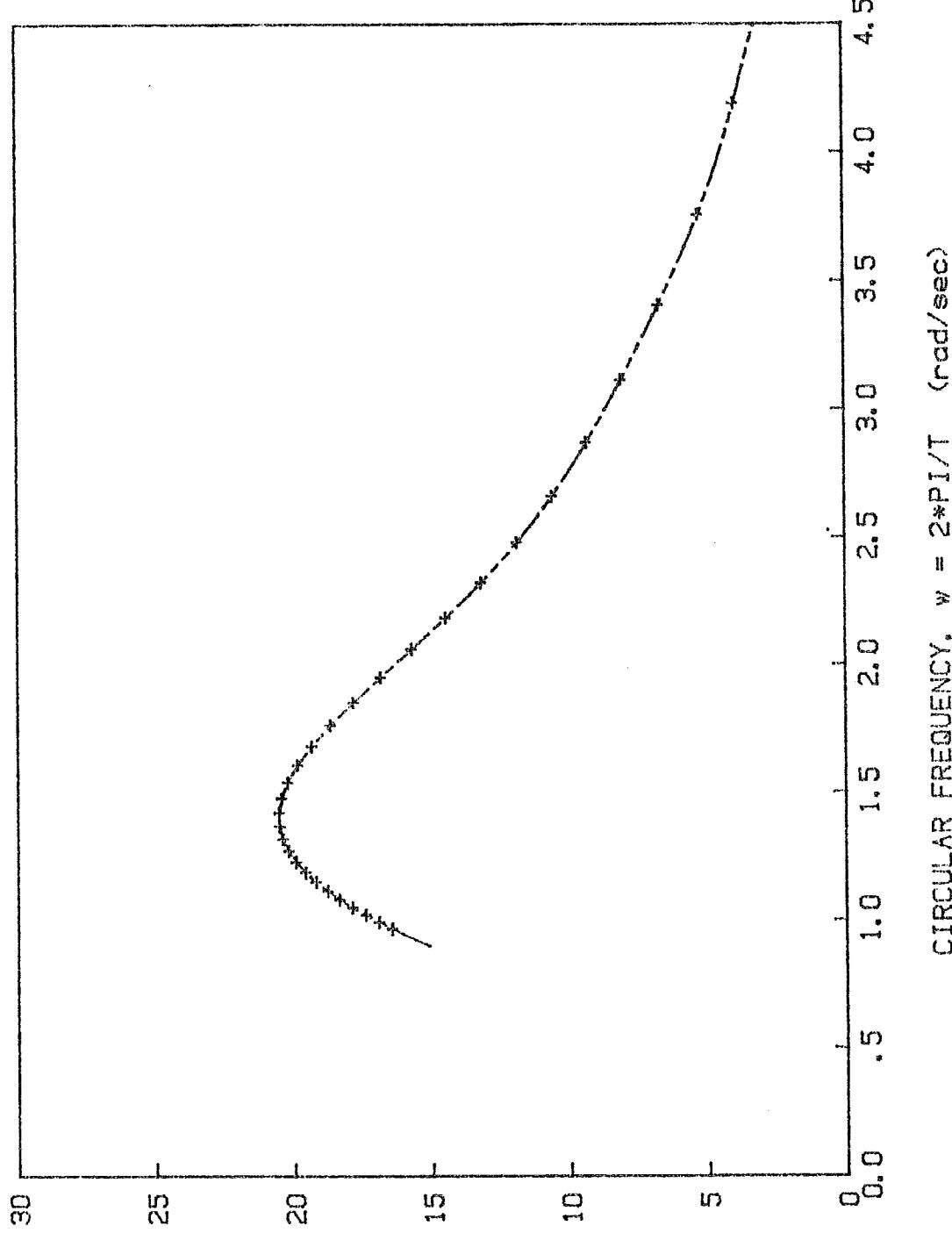
ROLL-SWAY ADDED MASS, kip-sec<sup>2</sup>

FIGURE 13-4

THE GLOSTEN ASSOCIATES, Inc.  
19 MAY 1983

FIGURE 13-4

NEW I-90 BRIDGE



SWAY DAMPING, kip-sec/ft

FIGURE 13-5

THE GLOSTEN ASSOCIATES, Inc.  
19 MAY 1983

FIGURE 13-5

NEW I-90 BRIDGE

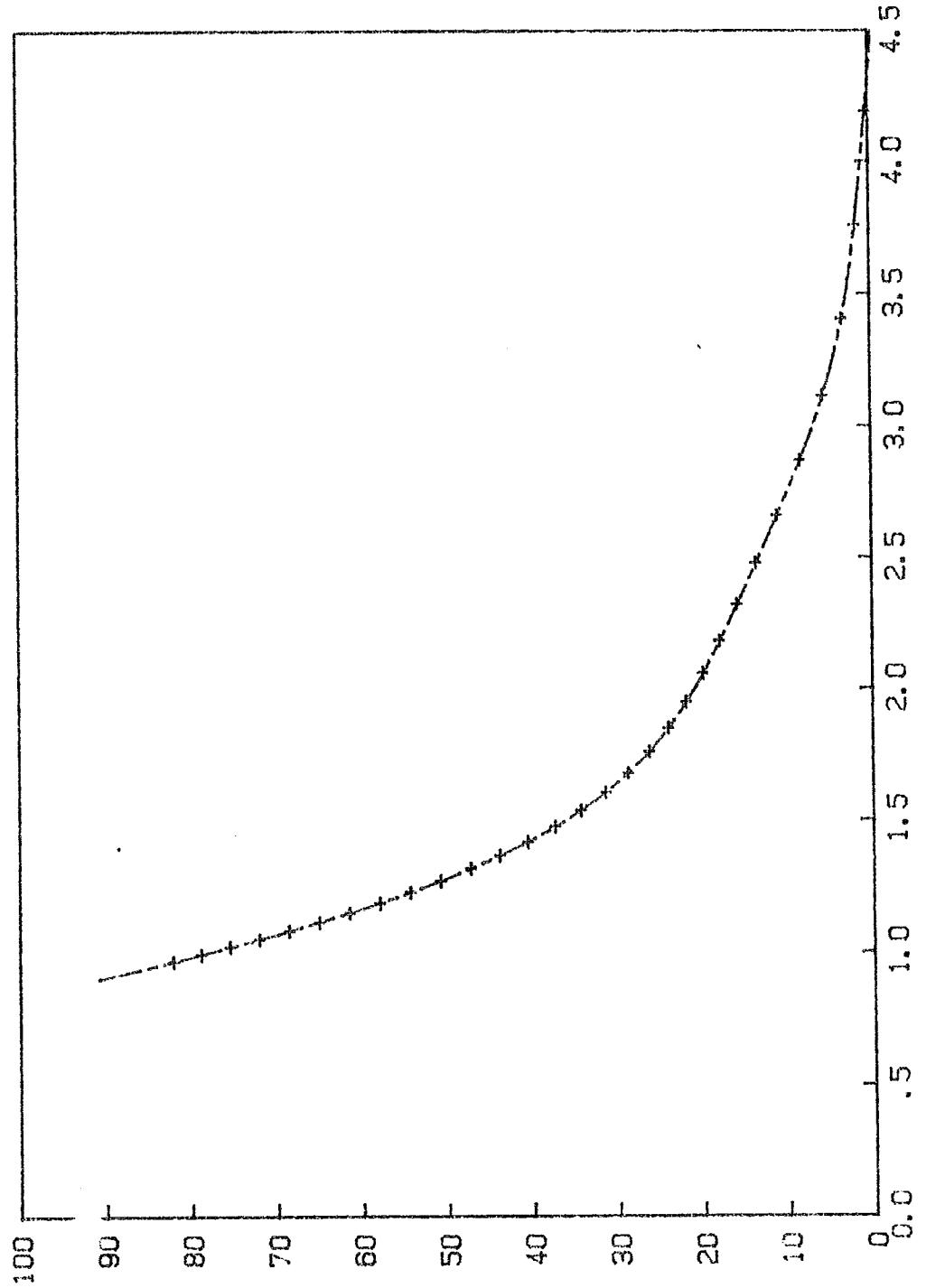
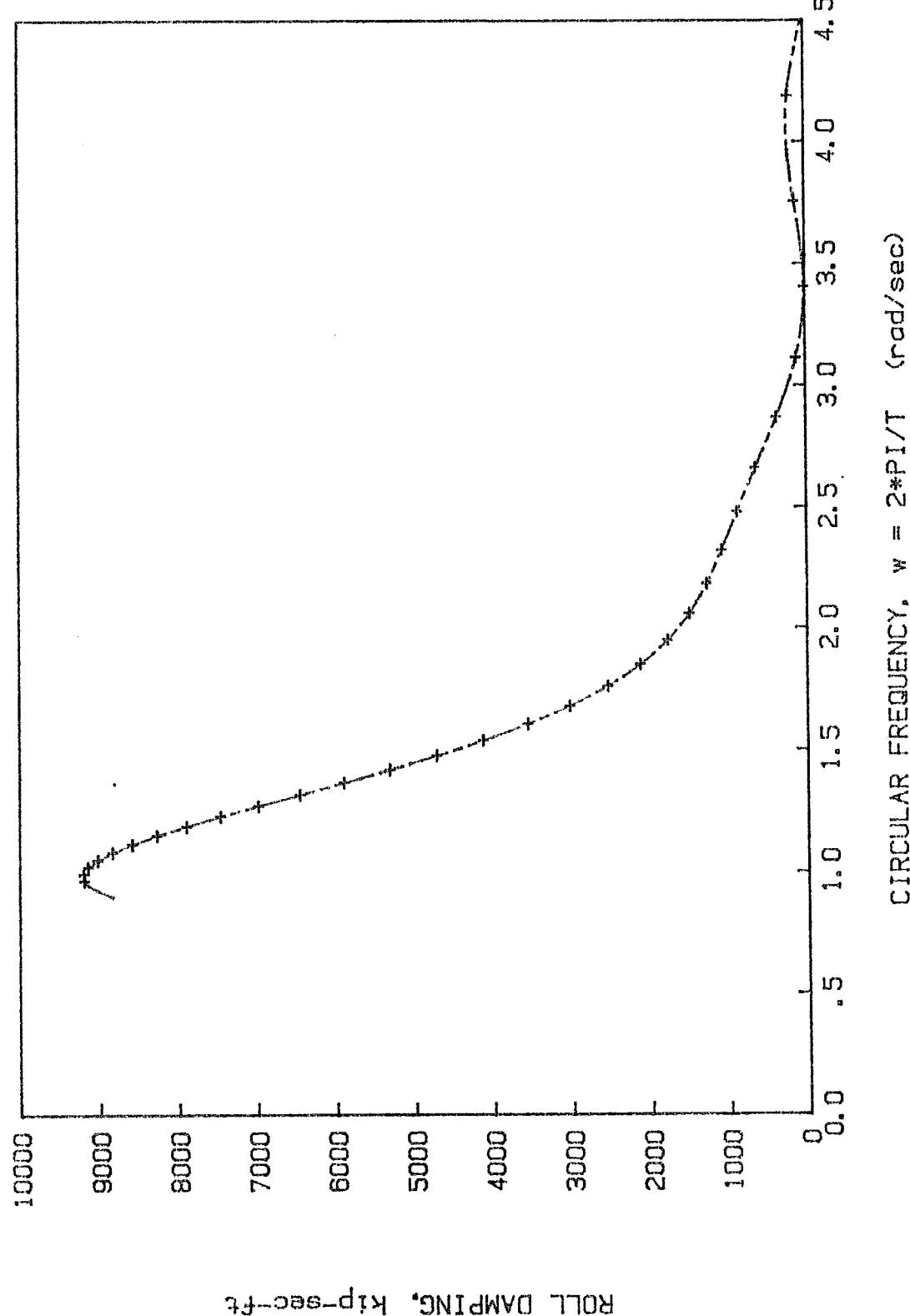


FIGURE 13-6

THE GLOSTEN ASSOCIATES, INC.  
19 MAY 1983

FIGURE 13-6

NEW I-90 BRIDGE



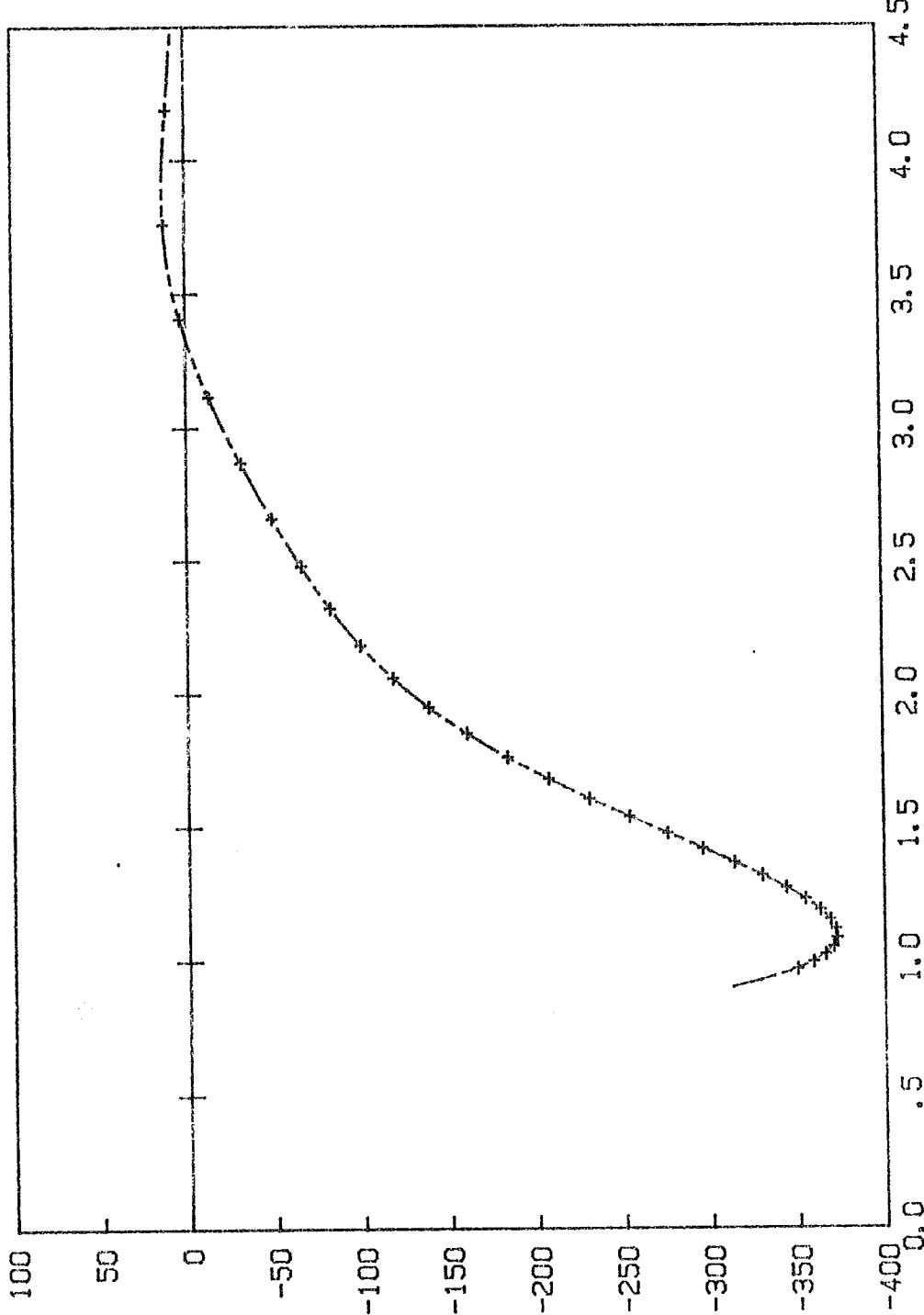
ROLL DAMPING, kip-sec-ft

FIGURE 13-7

THE GLOSTEN ASSOCIATES, INC.  
19 MAY 1983

FIGURE 13-7

NEW I-90 BRIDGE



ROLL-SWAY DAMPING, kip-sec

FIGURE 13-8

THE GLOSTEN ASSOCIATES, inc.  
19 MAY 1993

FIGURE 13-8

TABLE 13-9

FREQUENCY = 1.5377

## DIMENSIONAL ADDED MASS MATRIX

=====				
35.1929830768	0	534.111316931	0	0
0	1744.19784485	0	0	0
534.111316931	0	259916.537892	0	0
0	0	0	18410472.0871	0
0	0	0	0	387307.757417

FREQUENCY = 1.5377

## DIMENSIONAL DAMPING MATRIX

=====				
202.234743611	0	-2536.71038255	0	0
0	342.398932827	0	0	0
-2536.71038255	0	41217.8946268	0	0
0	0	0	3614111.79011	0
0	0	0	0	2225644.94884

#### 14. Wave Climatology

Wave modeling techniques are discussed in further detail in section 9 (Volume 1). The re-analysis of available wind statistics by Professor Richard Reed resulted in basic design wind conditions at the I-90/Lacey V. Murrow site as follows:

<u>Return Interval</u>	<u>Northerly Winds</u>	<u>Southerly Winds</u>
100 yrs	51 mph	63 mph
1 yr	34 mph	43 mph

These are defined as one-minute average winds, measured 30 feet above lake level. Further data were provided by Professor Reed for converting to other time averages. It was Professor Reed's opinion that north and south wind statistics should be treated separately and, further, that it would not be meaningful to develop a finer mesh of directional statistics beyond the basic north/south grouping.

Therefore the lake geometry, expressed as effective fetch distance to shore, versus wind heading and location over the length of the bridge, was analyzed to determine worst-case wave climatologies for north and south 100 year winds at this site. For north winds, the Evergreen Point Bridge was assumed to be in place, acting as a breakwater to limit the fetch distances. For south winds, it was assumed that the Lacey V. Murrow Bridge was not in place.

The resulting significant heights are shown in figures 14-1 through 14-4. It was concluded from these results that:

- . South winds clearly produce the most severe sea state.
- . Sea state is relatively insensitive to location on the bridge (see figure 14-1) or variation in heading angle within + 45 degrees of perpendicular to the bridge (see figure 14-2).

Parametric studies of the effect of wave heading on bridge structural responses indicated that beam seas, perpendicular to the bridge, result in maximum loads. It was therefore possible to simplify the analysis by considering only one central heading angle, and a uniform sea state over the entire length of the bridge, as a "design" condition. The resulting spectra, for 1 year and 100 year return intervals, are shown in figure 14-5 and 14-6.

A 12-th power cosine directional spreading function was used for all response results presented in this volume. The effects of varying this parameter are discussed in Section 9 (Volume I).

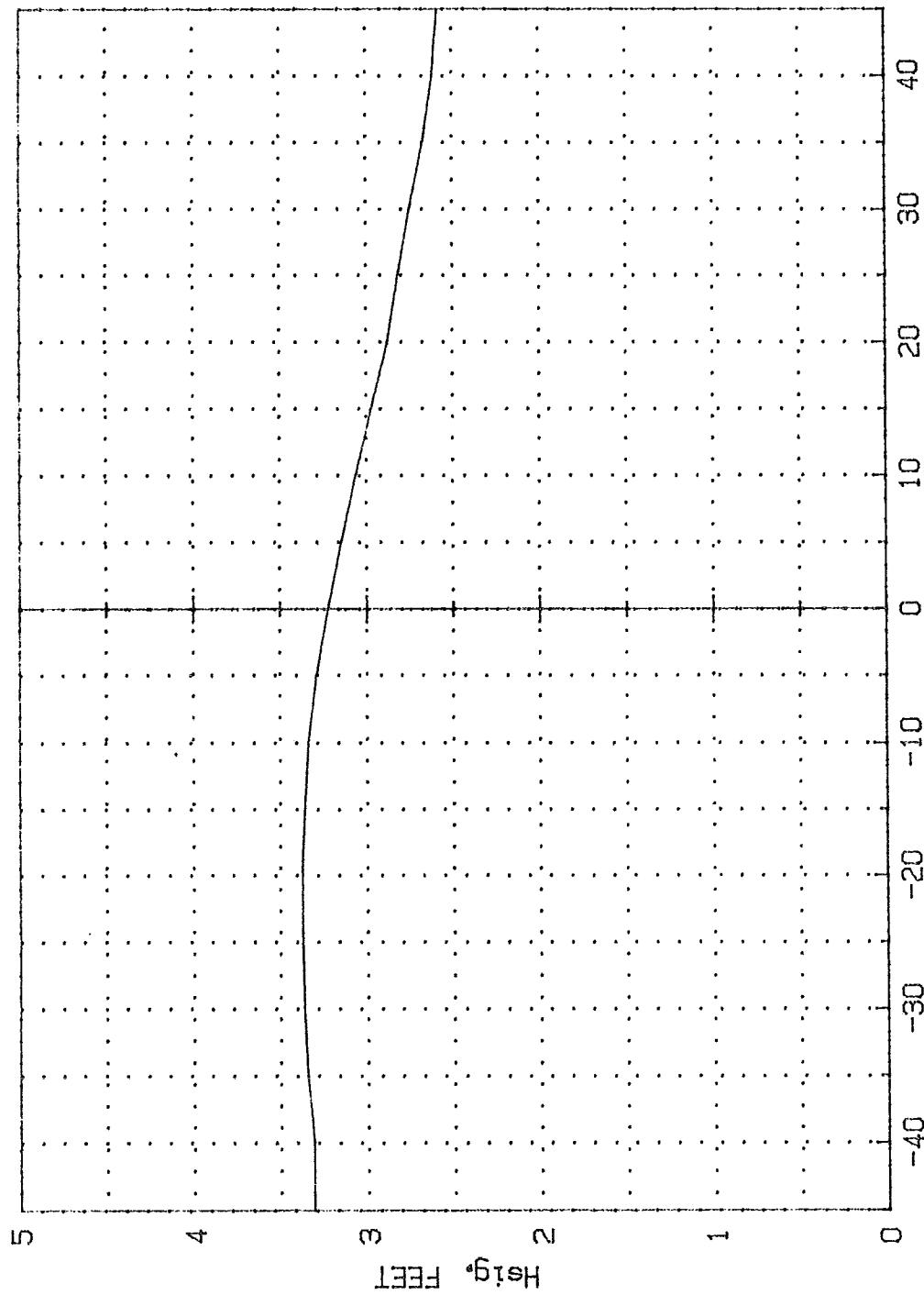


FIGURE 14-1

WIND DIRECTION, DEG  
NODE I/J. WIND DIRECTION: SOUTH  
THE GLOSTEN ASSOCIATES, INC  
20 MAY 1983

SEA HEIGHT VS DIRECTION

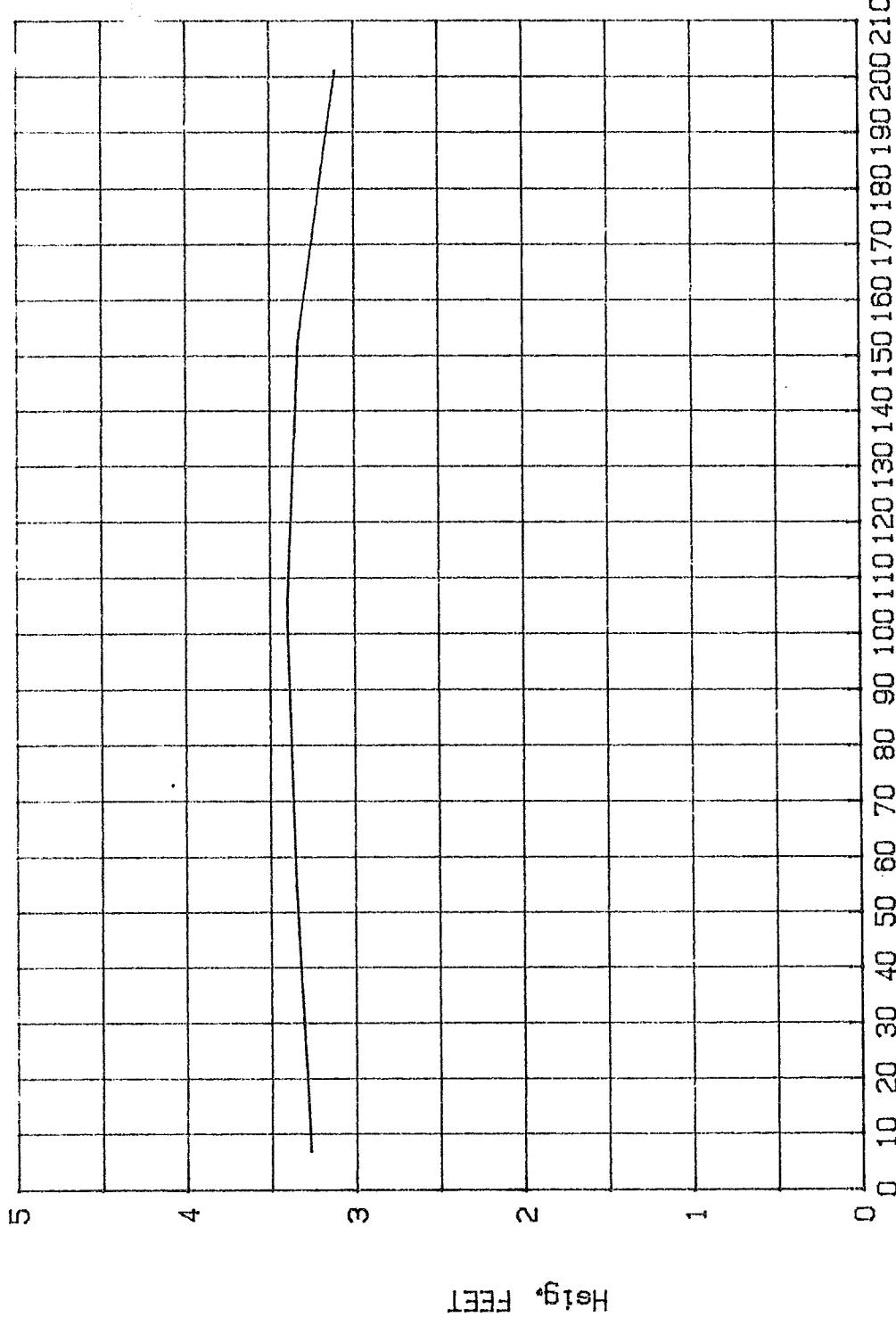


FIGURE 14-2  
THE GLOSTEN ASSOCIATES, inc  
20 MAY 1983  
WIND DIRECTION SOUTH  
SEA HEIGHT VS LOCATION

FIGURE 14-2

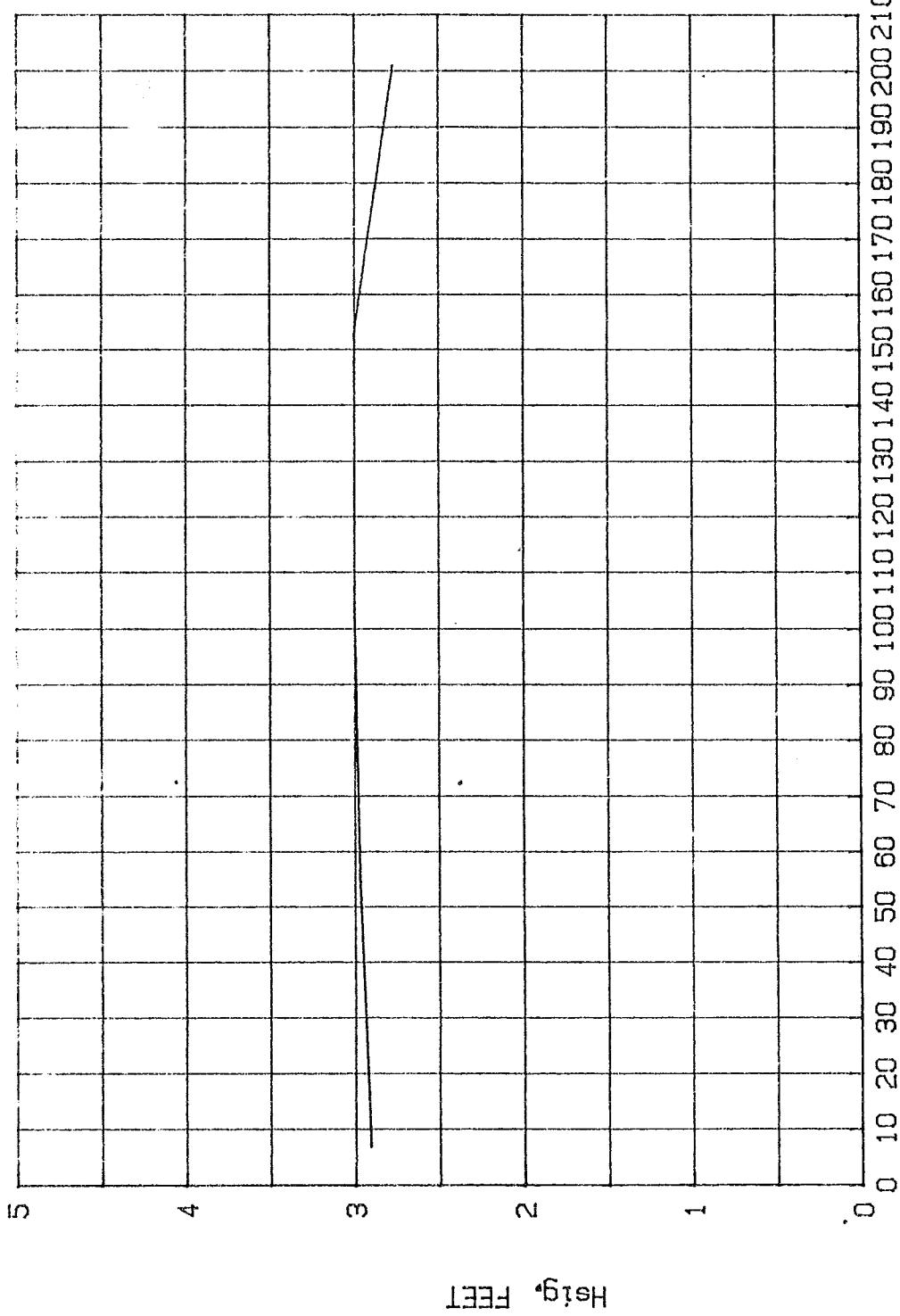


FIGURE 14-3  
THE GLOSTEN ASSOCIATES, Inc  
20 MAY 1983  
WIND DIRECTION NORTH  
SEA HEIGHT VS LOCATION

FIGURE 14-3

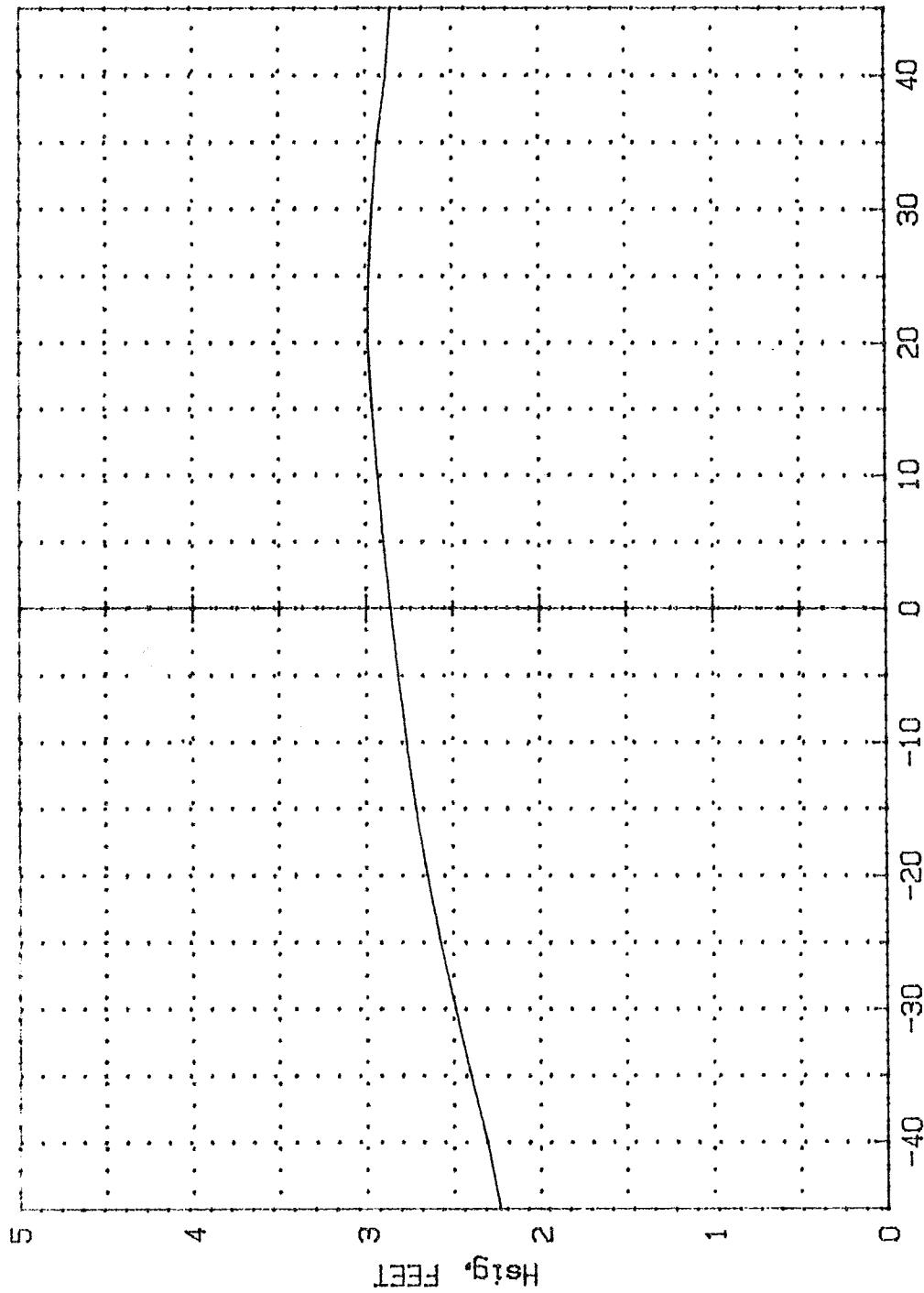


FIGURE 14-4

FIGURE 14-4  
THE GLOSTEN ASSOCIATES, inc  
20 MAY 1983

NODE I/J. WIND DIRECTION: NORTH  
SEA HEIGHT VS DIRECTION

# NEW I-90 BRIDGE

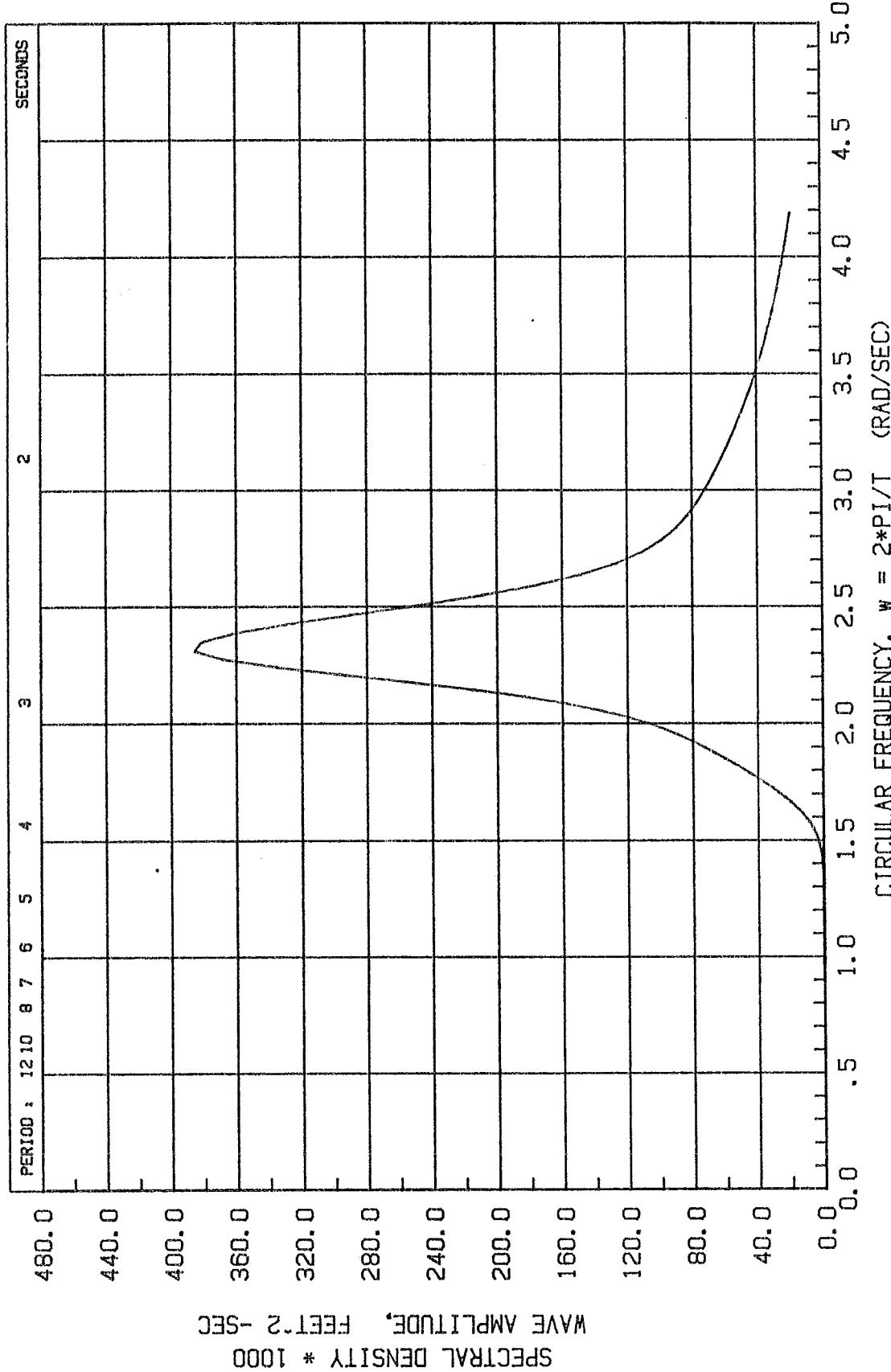


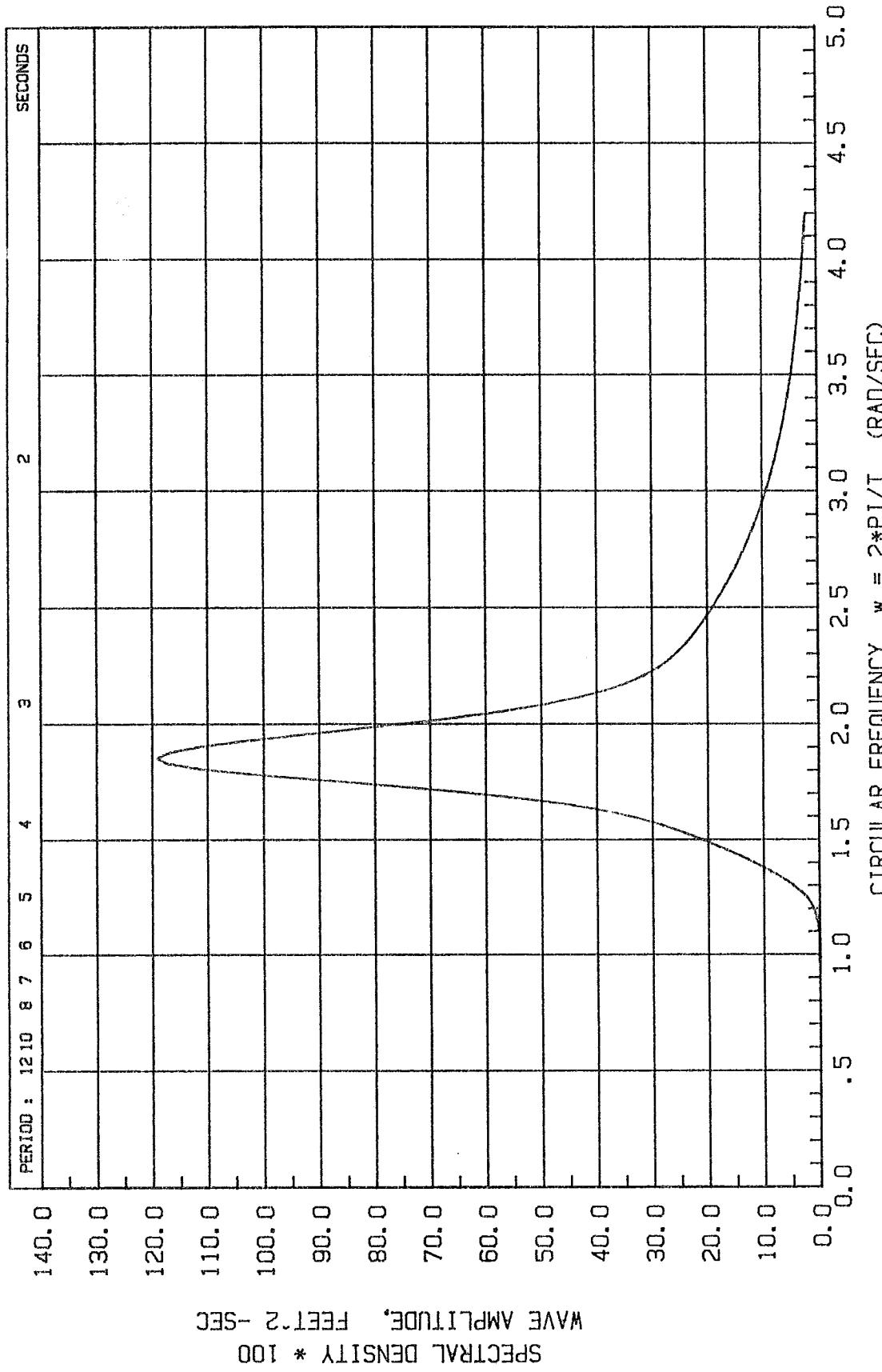
FIGURE 14-5

THE GLOSTEN ASSOCIATES, inc.  
11 MAY 1983

FIGURE 14-5

1 YEAR DESIGN SEA SPECTRUM

# NEW T-SO BRIDGE



JONSWOP WAVE SPECTRUM  
SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)

THE GLOSTEN ASSOCIATES, INC.  
11 MAY 1983

FIGURE 14-6

100 YEAR DESIGN SEA SPECTRUM

## 15. Results

Response statistics have been developed for five degree-of-freedom internal structural loads, motion responses and mooring line responses, in 1 and 100 year return interval storm conditions.

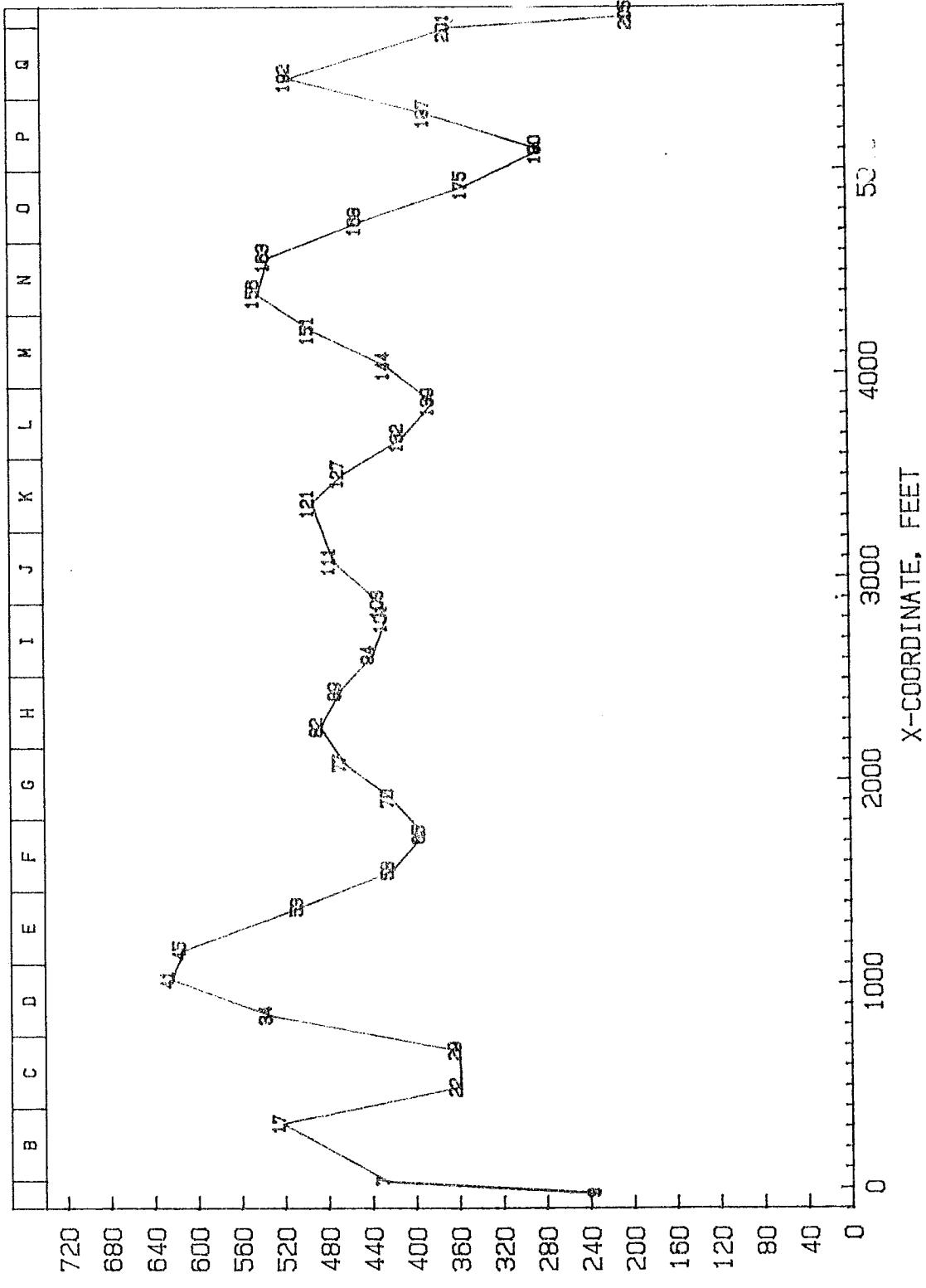
### 15.1 Load Responses

Internal load response statistics have been computed for five orthogonal degrees-of-freedom: Lateral shear, vertical shear, torsion, vertical bending, and lateral bending. Expected maximum responses (90% confidence, in one hour exposure) are plotted for a mesh of 34 nodes over the bridge length. Also, the most probable maximum response in one hour, and various averages, have been tabulated for the same 34 nodes, as follows:

<u>Response Node</u>	<u>Figure</u>	<u>Table</u>
100 yr. return interval		
Lateral shear	15-1	15-2
Vertical shear	15-3	15-4
Torsion	15-5	15-6
Vertical bending	15-7	15-8
Lateral bending	15-9	15-10
1 yr. return interval		
Lateral shear	15-11	15-12
Vertical shear	15-13	15-14
Torsion	15-15	15-16
Vertical bending	15-17	15-18
Lateral bending	15-19	15-20

To illustrate the frequency composition of the basic response statistics, selected spectra are presented as follows: for the 100 year storm condition in figures 15-21 through 15-25 and for the 1 year storm condition in figures 15-26 and 15-27.

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET  
 MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 6 MAY 1988

FIGURE 15-1

FIGURE 15-1

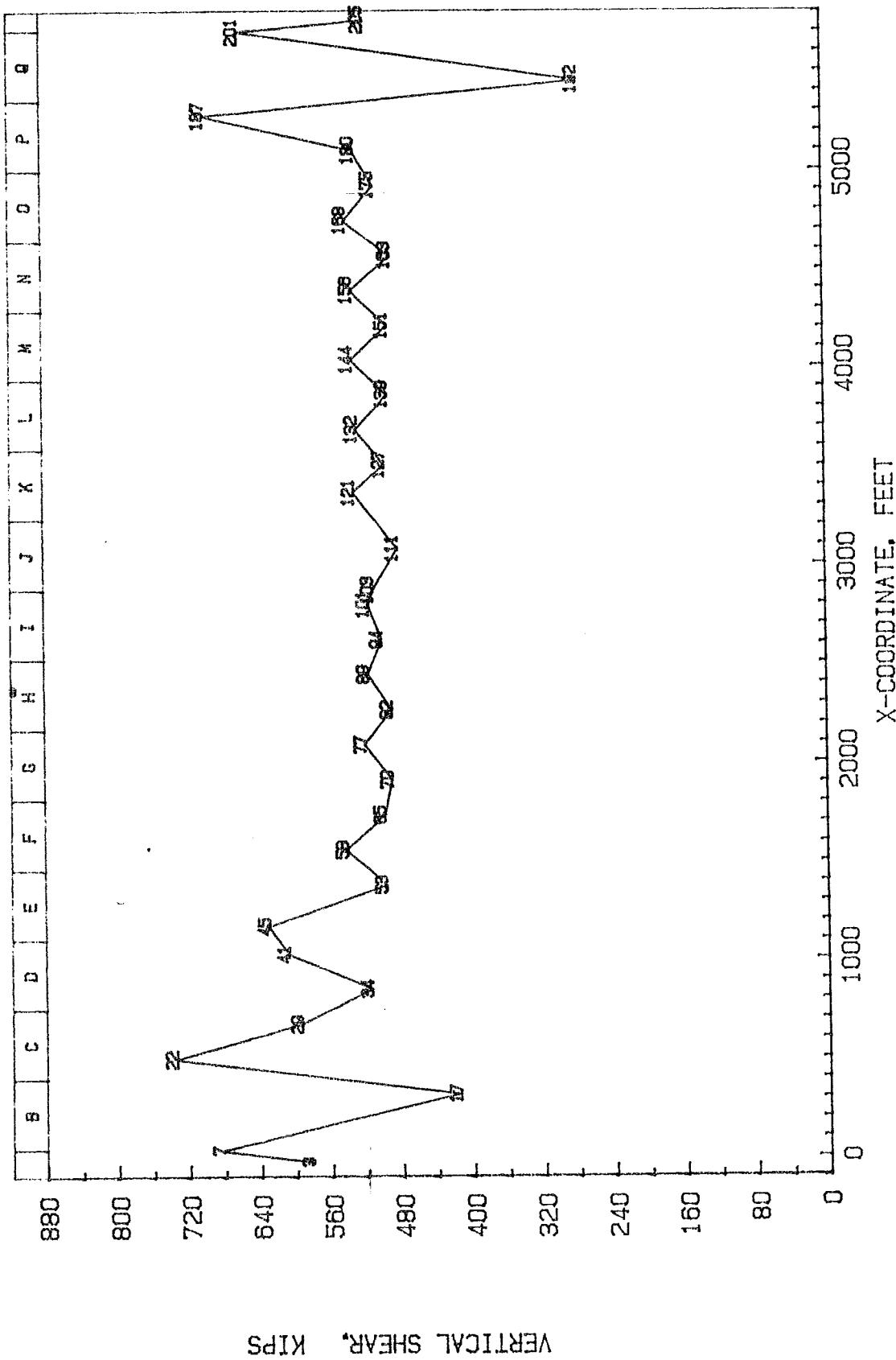
TABLE 15- 2  
\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 NODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

LATERAL SHEAR (KIPS)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	5.375E+001	1.075E+002	1.371E+002	2.012E+002	2.319E+002
7	9.873E+001	1.975E+002	2.518E+002	3.693E+002	4.258E+002
17	1.210E+002	2.420E+002	3.086E+002	4.514E+002	5.208E+002
22	8.332E+001	1.666E+002	2.125E+002	3.102E+002	3.580E+002
29	8.315E+001	1.663E+002	2.120E+002	3.119E+002	3.593E+002
34	1.233E+002	2.466E+002	3.144E+002	4.624E+002	5.327E+002
41	1.444E+002	2.888E+002	3.683E+002	5.401E+002	6.227E+002
45	1.421E+002	2.841E+002	3.623E+002	5.303E+002	6.117E+002
53	1.170E+002	2.340E+002	2.983E+002	4.358E+002	5.029E+002
58	9.752E+001	1.950E+002	2.487E+002	3.637E+002	4.196E+002
65	9.066E+001	1.813E+002	2.312E+002	3.389E+002	3.908E+002
70	9.726E+001	1.945E+002	2.480E+002	3.642E+002	4.197E+002
77	1.074E+002	2.149E+002	2.740E+002	4.021E+002	4.635E+002
82	1.123E+002	2.247E+002	2.864E+002	4.200E+002	4.843E+002
89	1.084E+002	2.168E+002	2.764E+002	4.049E+002	4.670E+002
94	1.014E+002	2.029E+002	2.587E+002	3.785E+002	4.367E+002
101	9.862E+001	1.972E+002	2.515E+002	3.679E+002	4.244E+002
103	9.935E+001	1.987E+002	2.533E+002	3.706E+002	4.276E+002
111	1.095E+002	2.191E+002	2.793E+002	4.092E+002	4.719E+002
121	1.139E+002	2.279E+002	2.905E+002	4.263E+002	4.914E+002
127	1.074E+002	2.148E+002	2.739E+002	4.021E+002	4.635E+002
132	9.469E+001	1.894E+002	2.415E+002	3.543E+002	4.085E+002
139	8.821E+001	1.764E+002	2.249E+002	3.295E+002	3.800E+002
144	9.787E+001	1.957E+002	2.496E+002	3.649E+002	4.210E+002
151	1.139E+002	2.279E+002	2.905E+002	4.248E+002	4.901E+002
156	1.254E+002	2.508E+002	3.197E+002	4.682E+002	5.400E+002
163	1.230E+002	2.459E+002	3.136E+002	4.601E+002	5.304E+002
168	1.033E+002	2.065E+002	2.633E+002	3.873E+002	4.462E+002
175	8.060E+001	1.612E+002	2.055E+002	3.025E+002	3.485E+002
180	6.489E+001	1.298E+002	1.655E+002	2.423E+002	2.795E+002
187	8.899E+001	1.780E+002	2.269E+002	3.317E+002	3.827E+002
192	1.184E+002	2.367E+002	3.018E+002	4.423E+002	5.101E+002
201	8.424E+001	1.685E+002	2.148E+002	3.155E+002	3.636E+002
205	4.530E+001	9.059E+001	1.155E+002	1.697E+002	1.956E+002

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET   MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12<sup>th</sup> POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.  
 6 MAY 1983

FIGURE 15-3

FIGURE 15-3

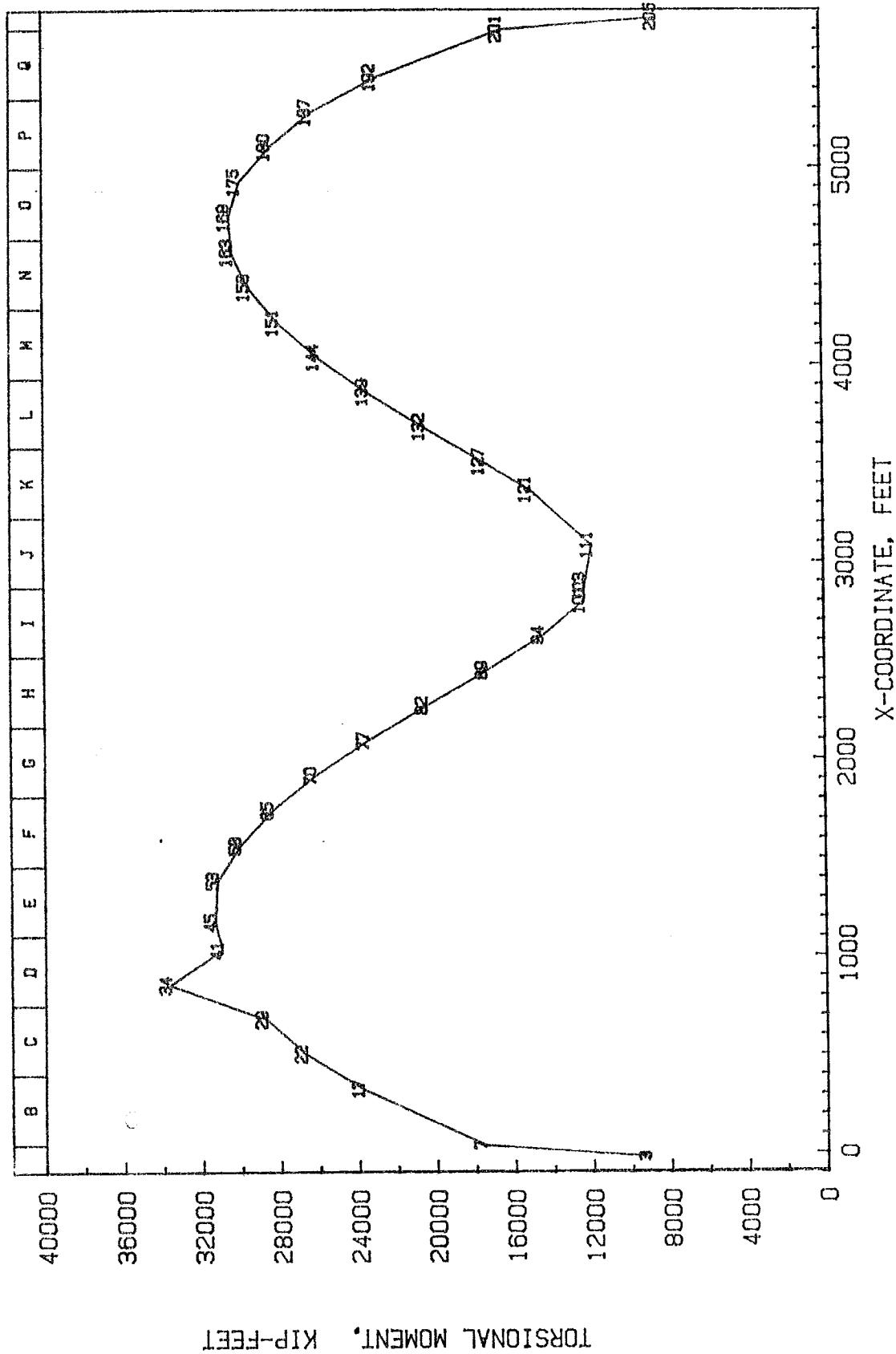
TABLE 15- 4  
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SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

VERTICAL SHEAR (KIPS)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.343E+002	2.687E+002	3.426E+002	5.061E+002	5.824E+002
7	1.576E+002	3.152E+002	4.019E+002	5.926E+002	6.824E+002
17	9.485E+001	1.897E+002	2.419E+002	3.619E+002	4.152E+002
22	1.701E+002	3.402E+002	4.337E+002	6.374E+002	7.346E+002
29	1.372E+002	2.745E+002	3.500E+002	5.152E+002	5.934E+002
34	1.180E+002	2.360E+002	3.009E+002	4.475E+002	5.142E+002
41	1.406E+002	2.812E+002	3.586E+002	5.275E+002	6.077E+002
45	1.450E+002	2.900E+002	3.698E+002	5.472E+002	6.295E+002
53	1.147E+002	2.294E+002	2.925E+002	4.315E+002	4.967E+002
58	1.244E+002	2.489E+002	3.173E+002	4.703E+002	5.408E+002
65	1.148E+002	2.295E+002	2.926E+002	4.327E+002	4.979E+002
70	1.128E+002	2.256E+002	2.876E+002	4.257E+002	4.897E+002
77	1.197E+002	2.393E+002	3.051E+002	4.521E+002	5.199E+002
82	1.129E+002	2.258E+002	2.879E+002	4.256E+002	4.898E+002
89	1.187E+002	2.374E+002	3.027E+002	4.486E+002	5.159E+002
94	1.154E+002	2.308E+002	2.943E+002	4.352E+002	5.008E+002
101	1.187E+002	2.373E+002	3.026E+002	4.482E+002	5.155E+002
103	1.176E+002	2.351E+002	2.998E+002	4.437E+002	5.104E+002
111	1.109E+002	2.218E+002	2.827E+002	4.190E+002	4.819E+002
121	1.223E+002	2.446E+002	3.119E+002	4.617E+002	5.310E+002
127	1.143E+002	2.287E+002	2.915E+002	4.317E+002	4.965E+002
132	1.214E+002	2.428E+002	3.096E+002	4.585E+002	5.274E+002
139	1.136E+002	2.271E+002	2.896E+002	4.281E+002	4.926E+002
144	1.223E+002	2.446E+002	3.119E+002	4.626E+002	5.318E+002
151	1.136E+002	2.271E+002	2.896E+002	4.275E+002	4.921E+002
156	1.223E+002	2.446E+002	3.119E+002	4.625E+002	5.318E+002
163	1.124E+002	2.248E+002	2.867E+002	4.245E+002	4.883E+002
168	1.243E+002	2.487E+002	3.170E+002	4.675E+002	5.383E+002
175	1.160E+002	2.320E+002	2.958E+002	4.412E+002	5.066E+002
180	1.229E+002	2.457E+002	3.133E+002	4.582E+002	5.287E+002
187	1.603E+002	3.206E+002	4.088E+002	6.068E+002	6.975E+002
192	6.299E+001	1.260E+002	1.606E+002	2.398E+002	2.753E+002
201	1.514E+002	3.029E+002	3.862E+002	5.720E+002	6.579E+002
205	1.188E+002	2.376E+002	3.029E+002	4.493E+002	5.165E+002

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET   MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12<sup>th</sup> POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 6 MAY 1963

FIGURE 15-5

FIGURE 15-5

TABLE 15-6

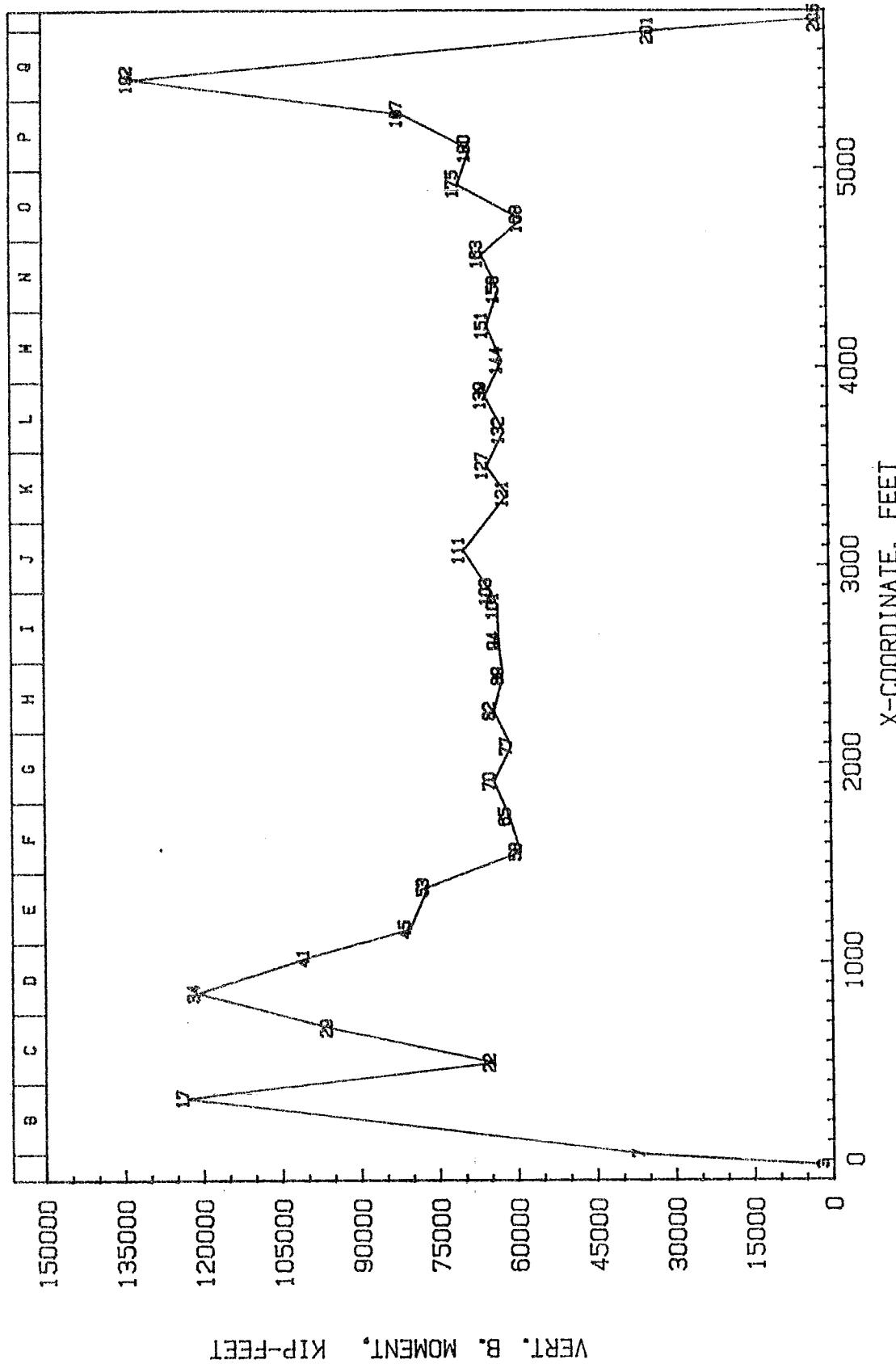
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SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## TORSIONAL MOMENT (KIP-FEET)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.119E+003	4.23BE+003	5.403E+003	7.940E+003	9.150E+003
7	4.073E+003	8.146E+003	1.039E+004	1.526E+004	1.759E+004
17	5.517E+003	1.103E+004	1.407E+004	2.067E+004	2.382E+004
22	1.193E+003	1.239E+004	1.579E+004	2.320E+004	2.674E+004
29	6.661E+003	1.332E+004	1.699E+004	2.495E+004	2.875E+004
34	7.810E+003	1.562E+004	1.992E+004	2.921E+004	3.387E+004
41	7.108E+003	1.438E+004	1.833E+004	2.690E+004	3.101E+004
45	7.265E+003	1.453E+004	1.853E+004	2.718E+004	3.134E+004
53	7.241E+003	1.448E+004	1.847E+004	2.708E+004	3.122E+004
58	6.971E+003	1.394E+004	1.778E+004	2.606E+004	3.005E+004
65	6.589E+003	1.318E+004	1.680E+004	2.463E+004	2.840E+004
70	6.074E+003	1.215E+004	1.549E+004	2.289E+004	2.617E+004
77	5.448E+003	1.090E+004	1.389E+004	2.034E+004	2.346E+004
82	4.748E+003	9.496E+003	1.211E+004	1.771E+004	2.043E+004
89	4.031E+003	8.062E+003	1.028E+004	1.502E+004	1.733E+004
94	3.363E+003	6.727E+003	8.577E+003	1.252E+004	1.445E+004
101	2.874E+003	5.748E+003	7.329E+003	1.068E+004	1.233E+004
103	2.870E+003	5.740E+003	7.31BE+003	1.066E+004	1.231E+004
111	2.778E+003	5.557E+003	7.085E+003	1.032E+004	1.192E+004
121	3.504E+003	7.008E+003	8.935E+003	1.306E+004	1.507E+004
127	4.054E+003	8.109E+003	1.034E+004	1.513E+004	1.745E+004
132	4.760E+003	9.519E+003	1.214E+004	1.778E+004	2.050E+004
139	5.430E+003	1.086E+004	1.385E+004	2.029E+004	2.340E+004
144	6.013E+003	1.203E+004	1.533E+004	2.248E+004	2.592E+004
151	6.486E+003	1.297E+004	1.654E+004	2.426E+004	2.797E+004
156	6.827E+003	1.365E+004	1.741E+004	2.554E+004	2.945E+004
163	7.025E+003	1.405E+004	1.791E+004	2.629E+004	3.031E+004
168	7.056E+003	1.411E+004	1.799E+004	2.641E+004	3.045E+004
175	6.931E+003	1.386E+004	1.767E+004	2.595E+004	2.991E+004
180	6.568E+003	1.314E+004	1.675E+004	2.460E+004	2.835E+004
187	6.082E+003	1.216E+004	1.551E+004	2.278E+004	2.625E+004
192	5.309E+003	1.062E+004	1.354E+004	1.988E+004	2.292E+004
201	3.798E+003	7.596E+003	9.485E+003	1.423E+004	1.640E+004
205	1.953E+003	3.906E+003	4.980E+003	7.316E+003	8.431E+003

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.  
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FIGURE 15-7

FIGURE 15-7

TABLE 15-8

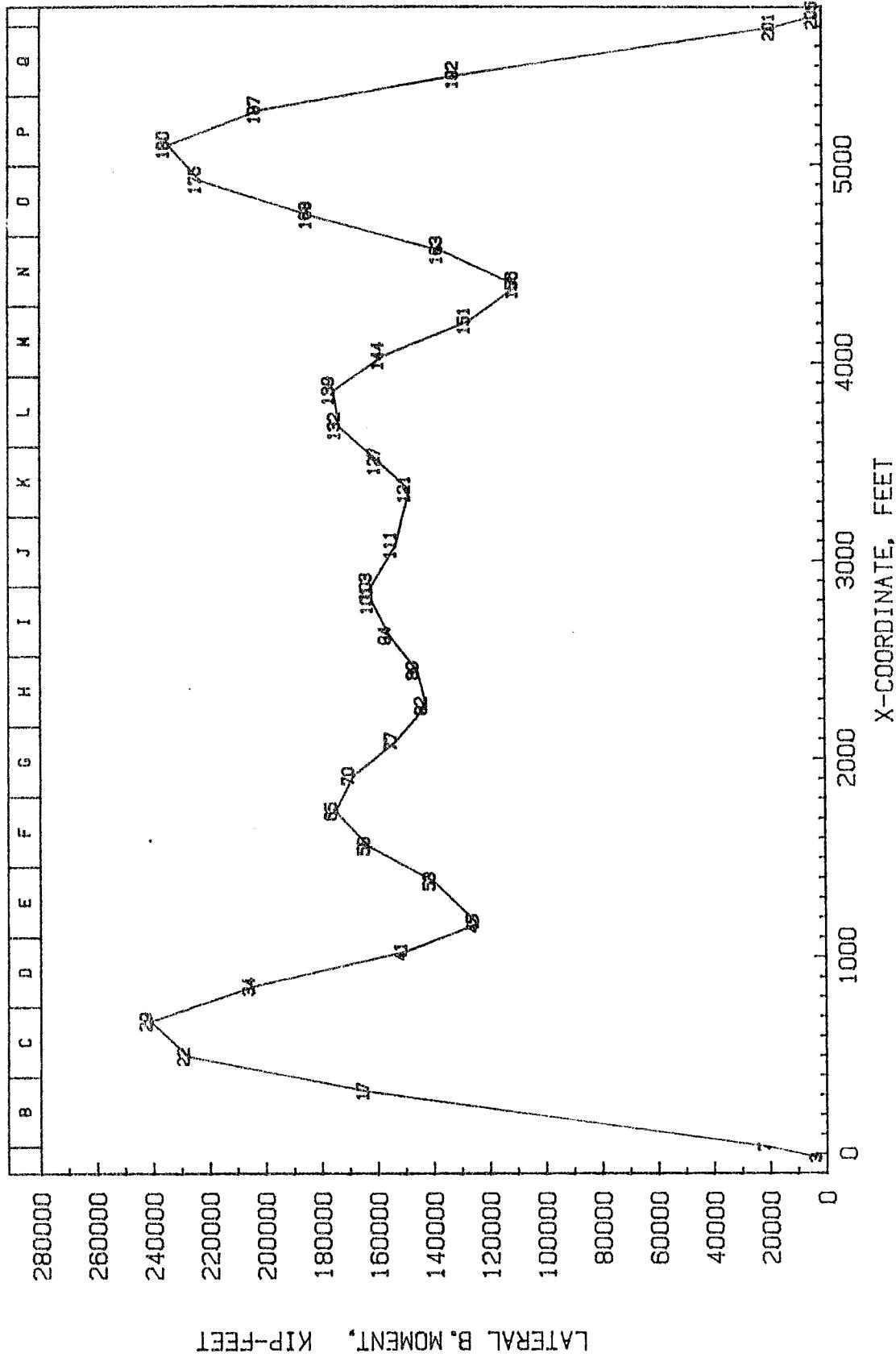
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SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## VERT. B. MOMENT (KIP-FEET)

NODE	RHS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.297E+002	4.595E+002	5.858E+002	8.712E+002	1.001E+003
7	8.352E+003	1.670E+004	2.130E+004	3.147E+004	3.621E+004
17	2.860E+004	5.720E+004	7.292E+004	1.066E+005	1.230E+005
22	1.488E+004	2.976E+004	3.794E+004	5.598E+004	6.445E+004
29	2.209E+004	4.418E+004	5.633E+004	8.294E+004	9.553E+004
34	2.807E+004	5.613E+004	7.157E+004	1.047E+005	1.208E+005
41	2.310E+004	4.619E+004	5.890E+004	8.678E+004	9.992E+004
45	1.863E+004	3.726E+004	4.750E+004	6.981E+004	8.045E+004
53	1.779E+004	3.557E+004	4.535E+004	6.685E+004	7.698E+004
58	1.371E+004	2.742E+004	3.496E+004	5.133E+004	5.916E+004
65	1.414E+004	2.828E+004	3.605E+004	5.314E+004	6.119E+004
70	1.483E+004	2.967E+004	3.783E+004	5.567E+004	6.413E+004
77	1.408E+004	2.816E+004	3.590E+004	5.280E+004	6.084E+004
82	1.480E+004	2.959E+004	3.773E+004	5.560E+004	6.403E+004
89	1.444E+004	2.887E+004	3.681E+004	5.412E+004	6.236E+004
94	1.459E+004	2.917E+004	3.720E+004	5.481E+004	6.312E+004
101	1.463E+004	2.926E+004	3.731E+004	5.489E+004	6.323E+004
103	1.491E+004	2.983E+004	3.803E+004	5.599E+004	6.449E+004
111	1.613E+004	3.226E+004	4.113E+004	6.051E+004	6.971E+004
121	1.416E+004	2.832E+004	3.611E+004	5.314E+004	6.122E+004
127	1.506E+004	3.012E+004	3.840E+004	5.654E+004	6.512E+004
132	1.432E+004	2.863E+004	3.651E+004	5.369E+004	6.186E+004
139	1.512E+004	3.023E+004	3.854E+004	5.682E+004	6.543E+004
144	1.441E+004	2.882E+004	3.674E+004	5.396E+004	6.219E+004
151	1.501E+004	3.001E+004	3.827E+004	5.646E+004	6.500E+004
156	1.453E+004	2.906E+004	3.706E+004	5.443E+004	6.273E+004
163	1.523E+004	3.046E+004	3.884E+004	5.719E+004	6.587E+004
168	1.342E+004	2.684E+004	3.422E+004	5.055E+004	5.818E+004
175	1.637E+004	3.275E+004	4.175E+004	6.105E+004	7.044E+004
180	1.560E+004	3.120E+004	3.979E+004	5.924E+004	6.805E+004
187	1.891E+004	3.783E+004	4.823E+004	7.016E+004	8.106E+004
192	3.067E+004	6.135E+004	7.822E+004	1.152E+005	1.326E+005
201	7.562E+003	1.512E+004	1.928E+004	2.861E+004	3.289E+004
205	2.118E+002	4.236E+002	5.401E+002	8.036E+002	9.233E+002

# NEW T-SO BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12<sup>th</sup> POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.

6 MAY 1983

FIGURE 15-9

FIGURE 15-9

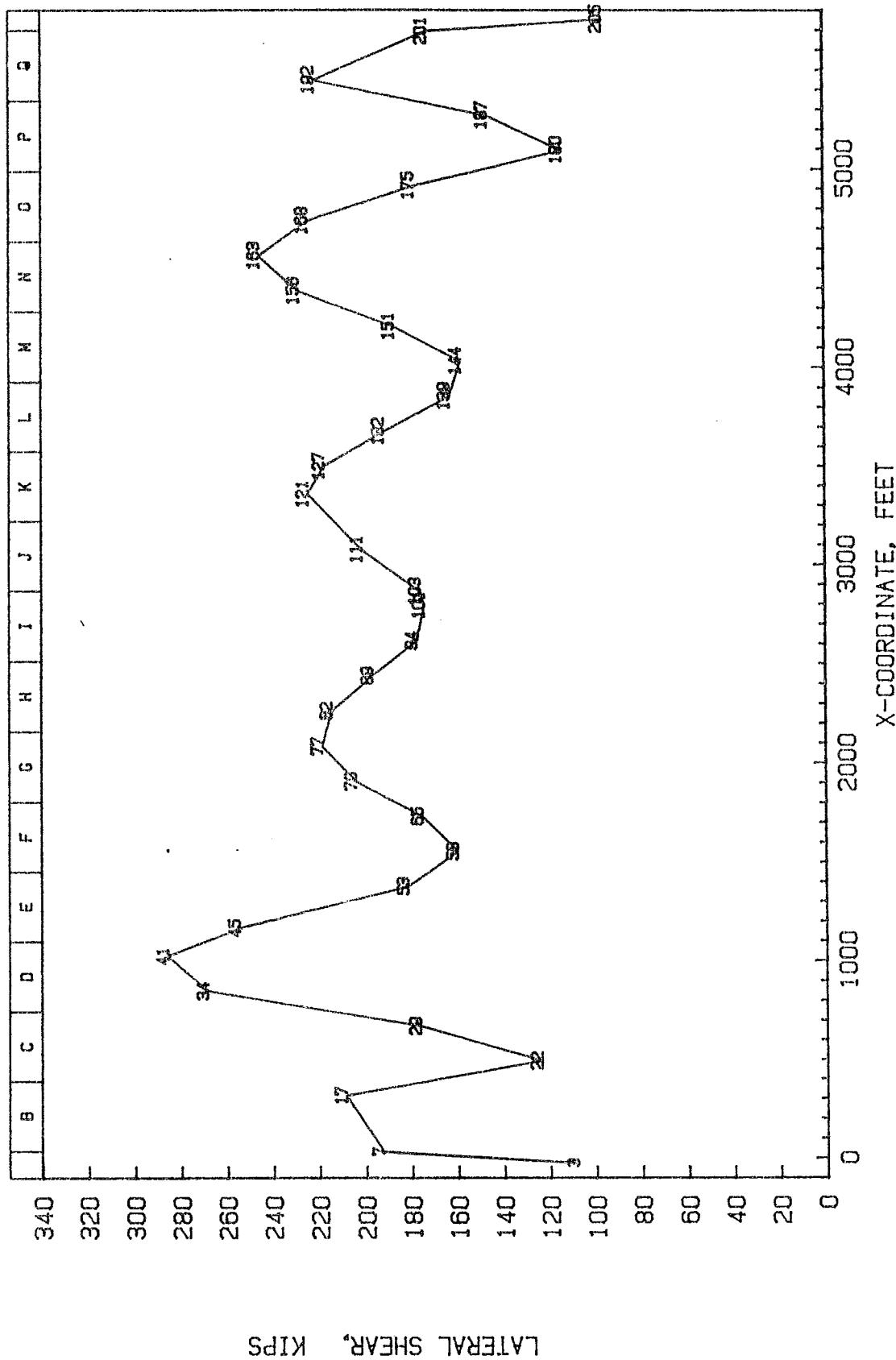
TABLE 15-10  
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SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

LATERAL B. MOMENT (KIP-FEET)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	5.095E+002	1.019E+003	1.299E+003	1.914E+003	2.205E+003
7	4.758E+003	9.516E+003	1.213E+004	1.782E+004	2.054E+004
17	3.798E+004	7.596E+004	9.684E+004	1.420E+005	1.637E+005
22	5.284E+004	1.057E+005	1.348E+005	1.973E+005	2.276E+005
29	5.601E+004	1.120E+005	1.428E+005	2.087E+005	2.408E+005
34	4.757E+004	9.515E+004	1.213E+005	1.768E+005	2.042E+005
41	3.495E+004	6.990E+004	8.912E+004	1.298E+005	1.499E+005
45	2.886E+004	5.771E+004	7.358E+004	1.076E+005	1.242E+005
53	3.231E+004	6.462E+004	8.240E+004	1.211E+005	1.396E+005
58	3.779E+004	7.557E+004	9.635E+004	1.414E+005	1.630E+005
65	4.056E+004	8.112E+004	1.034E+005	1.514E+005	1.747E+005
70	3.919E+004	7.838E+004	9.993E+004	1.460E+005	1.685E+005
77	3.565E+004	7.130E+004	9.091E+004	1.326E+005	1.531E+005
82	3.310E+004	6.619E+004	8.440E+004	1.232E+005	1.422E+005
89	3.374E+004	6.748E+004	8.604E+004	1.259E+005	1.452E+005
94	3.601E+004	7.202E+004	9.183E+004	1.346E+005	1.552E+005
101	3.748E+004	7.496E+004	9.557E+004	1.402E+005	1.616E+005
103	3.756E+004	7.511E+004	9.577E+004	1.404E+005	1.619E+005
111	3.555E+004	7.110E+004	9.065E+004	1.327E+005	1.530E+005
121	3.448E+004	6.896E+004	8.792E+004	1.282E+005	1.480E+005
127	3.699E+004	7.397E+004	9.432E+004	1.376E+005	1.588E+005
132	4.025E+004	8.050E+004	1.026E+005	1.500E+005	1.731E+005
139	4.067E+004	8.134E+004	1.037E+005	1.519E+005	1.752E+005
144	3.648E+004	7.295E+004	9.302E+004	1.365E+005	1.574E+005
151	2.929E+004	5.857E+004	7.468E+004	1.097E+005	1.265E+005
156	2.537E+004	5.073E+004	6.469E+004	9.466E+004	1.092E+005
163	3.176E+004	6.351E+004	8.098E+004	1.179E+005	1.362E+005
168	4.267E+004	8.534E+004	1.088E+005	1.587E+005	1.832E+005
175	5.174E+004	1.035E+005	1.319E+005	1.929E+005	2.225E+005
180	5.431E+004	1.086E+005	1.385E+005	2.028E+005	2.339E+005
187	4.668E+004	9.337E+004	1.190E+005	1.746E+005	2.013E+005
192	3.022E+004	6.044E+004	7.706E+004	1.131E+005	1.304E+005
201	3.887E+003	7.774E+003	9.912E+003	1.457E+004	1.679E+004
205	3.794E+002	7.588E+002	9.674E+002	1.426E+003	1.642E+003

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET      MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 10 MAY 1983

FIGURE 15-11

FIGURE 15-11

TABLE 15-12

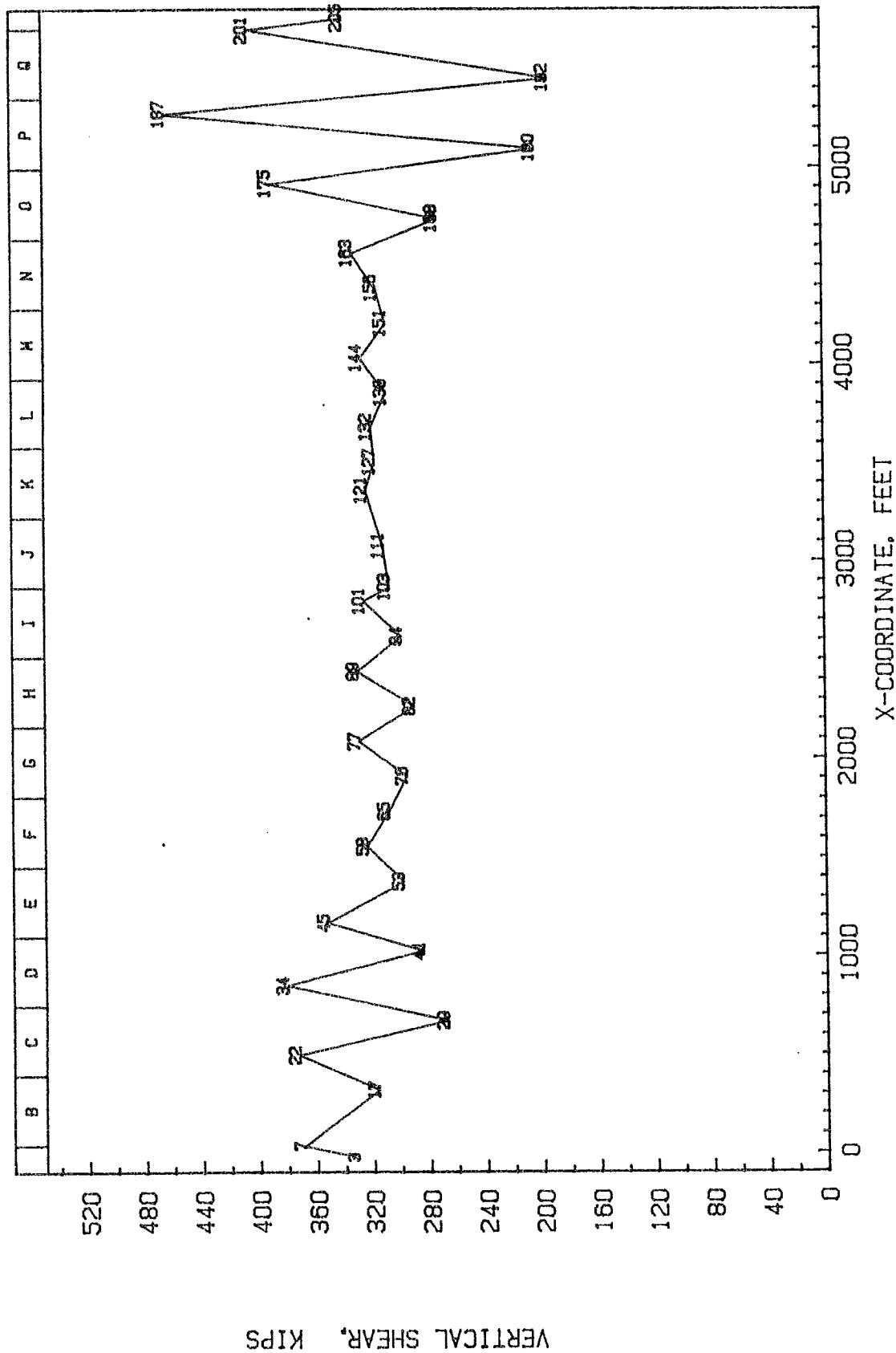
\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## LATERAL SHEAR (KIPS)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.476E+001	4.952E+001	6.313E+001	9.403E+001	1.080E+002
7	4.415E+001	8.829E+001	1.126E+002	1.676E+002	1.925E+002
17	4.796E+001	9.592E+001	1.223E+002	1.815E+002	2.086E+002
22	2.839E+001	5.678E+001	7.240E+001	1.075E+002	1.235E+002
29	4.024E+001	8.048E+001	1.026E+002	1.536E+002	1.762E+002
34	6.145E+001	1.229E+002	1.567E+002	2.337E+002	2.683E+002
41	6.560E+001	1.312E+002	1.673E+002	2.486E+002	2.857E+002
45	5.850E+001	1.170E+002	1.492E+002	2.212E+002	2.543E+002
53	4.164E+001	8.329E+001	1.062E+002	1.577E+002	1.812E+002
58	3.654E+001	7.307E+001	9.316E+001	1.392E+002	1.597E+002
65	4.004E+001	8.007E+001	1.021E+002	1.525E+002	1.751E+002
70	4.677E+001	9.354E+001	1.193E+002	1.776E+002	2.040E+002
77	5.015E+001	1.003E+002	1.279E+002	1.900E+002	2.183E+002
82	4.925E+001	9.849E+001	1.256E+002	1.864E+002	2.143E+002
89	4.513E+001	9.026E+001	1.151E+002	1.711E+002	1.966E+002
94	4.063E+001	8.125E+001	1.036E+002	1.544E+002	1.773E+002
101	3.986E+001	7.973E+001	1.017E+002	1.516E+002	1.741E+002
103	4.026E+001	8.052E+001	1.027E+002	1.531E+002	1.758E+002
111	4.618E+001	9.236E+001	1.178E+002	1.751E+002	2.012E+002
121	5.158E+001	1.032E+002	1.315E+002	1.953E+002	2.245E+002
127	4.994E+001	9.988E+001	1.274E+002	1.892E+002	2.175E+002
132	4.391E+001	8.782E+001	1.120E+002	1.668E+002	1.916E+002
139	3.726E+001	7.451E+001	9.500E+001	1.420E+002	1.629E+002
144	3.619E+001	7.237E+001	9.228E+001	1.376E+002	1.580E+002
151	4.304E+001	8.607E+001	1.097E+002	1.628E+002	1.872E+002
156	5.252E+001	1.050E+002	1.339E+002	1.986E+002	2.283E+002
163	5.630E+001	1.126E+002	1.436E+002	2.134E+002	2.452E+002
168	5.140E+001	1.028E+002	1.311E+002	1.955E+002	2.244E+002
175	4.076E+001	8.152E+001	1.039E+002	1.554E+002	1.783E+002
180	2.603E+001	5.205E+001	6.637E+001	9.910E+001	1.138E+002
187	3.368E+001	6.735E+001	8.587E+001	1.273E+002	1.464E+002
192	5.089E+001	1.018E+002	1.298E+002	1.929E+002	2.217E+002
201	3.951E+001	7.902E+001	1.008E+002	1.501E+002	1.724E+002
205	2.206E+001	4.412E+001	5.625E+001	8.385E+001	9.629E+001

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET      MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 10 MAY 1983

FIGURE 15-13

FIGURE 15-13

TABLE 15-14

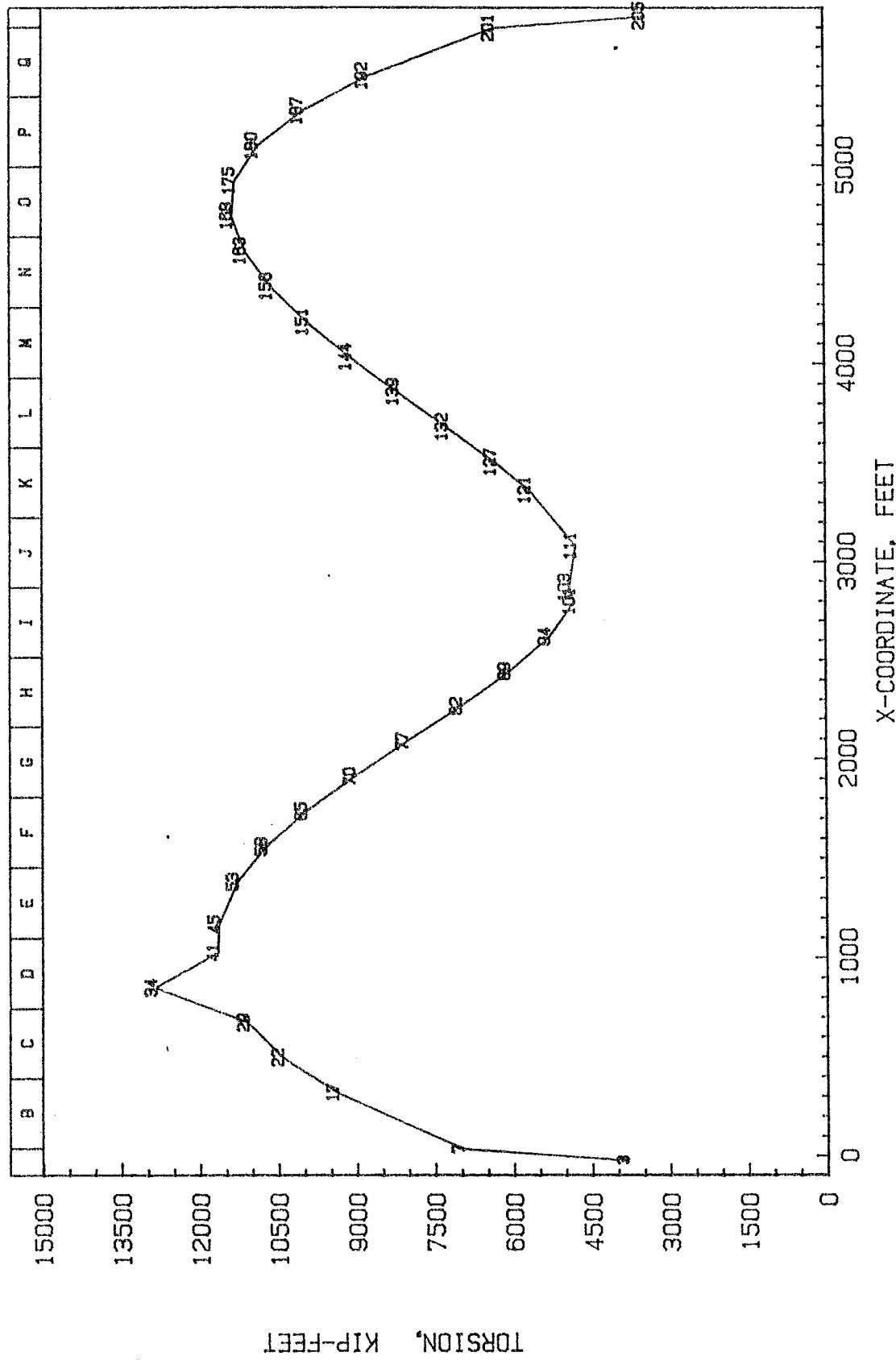
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SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## VERTICAL SHEAR (KIPS)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	7.564E+001	1.513E+002	1.929E+002	2.886E+002	3.311E+002
7	8.413E+001	1.683E+002	2.145E+002	3.214E+002	3.686E+002
17	7.188E+001	1.438E+002	1.833E+002	2.761E+002	3.163E+002
22	8.525E+001	1.705E+002	2.174E+002	3.240E+002	3.721E+002
29	6.070E+001	1.214E+002	1.548E+002	2.334E+002	2.673E+002
34	8.682E+001	1.736E+002	2.214E+002	3.318E+002	3.805E+002
41	6.509E+001	1.302E+002	1.660E+002	2.479E+002	2.846E+002
45	7.984E+001	1.597E+002	2.036E+002	3.068E+002	3.514E+002
53	6.827E+001	1.365E+002	1.741E+002	2.597E+002	2.982E+002
58	7.361E+001	1.472E+002	1.877E+002	2.822E+002	3.234E+002
65	7.036E+001	1.407E+002	1.794E+002	2.688E+002	3.083E+002
70	6.733E+001	1.347E+002	1.717E+002	2.576E+002	2.953E+002
77	7.502E+001	1.500E+002	1.913E+002	2.871E+002	3.292E+002
82	6.614E+001	1.323E+002	1.687E+002	2.529E+002	2.900E+002
89	7.520E+001	1.504E+002	1.918E+002	2.877E+002	3.299E+002
94	6.815E+001	1.363E+002	1.738E+002	2.608E+002	2.990E+002
101	7.416E+001	1.483E+002	1.891E+002	2.837E+002	3.253E+002
103	7.003E+001	1.401E+002	1.786E+002	2.679E+002	3.072E+002
111	7.094E+001	1.419E+002	1.809E+002	2.715E+002	3.113E+002
121	7.372E+001	1.474E+002	1.880E+002	2.819E+002	3.233E+002
127	7.229E+001	1.446E+002	1.843E+002	2.766E+002	3.171E+002
132	7.283E+001	1.457E+002	1.857E+002	2.787E+002	3.195E+002
139	7.048E+001	1.410E+002	1.797E+002	2.694E+002	3.089E+002
144	7.437E+001	1.487E+002	1.896E+002	2.849E+002	3.265E+002
151	7.054E+001	1.411E+002	1.799E+002	2.692E+002	3.089E+002
156	7.182E+001	1.436E+002	1.832E+002	2.753E+002	3.155E+002
163	7.591E+001	1.519E+002	1.936E+002	2.900E+002	3.326E+002
168	6.208E+001	1.242E+002	1.583E+002	2.374E+002	2.722E+002
175	8.876E+001	1.775E+002	2.263E+002	3.399E+002	3.896E+002
180	4.636E+001	9.271E+001	1.182E+002	1.785E+002	2.026E+002
187	1.058E+002	2.117E+002	2.699E+002	4.051E+002	4.644E+002
192	4.381E+001	8.763E+001	1.117E+002	1.686E+002	1.930E+002
201	9.237E+001	1.847E+002	2.355E+002	3.537E+002	4.054E+002
205	7.719E+001	1.544E+002	1.968E+002	2.950E+002	3.383E+002

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES ( WIND FROM SOUTH )  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 10 MAY 1983

FIGURE 15-15

FIGURE 15-15

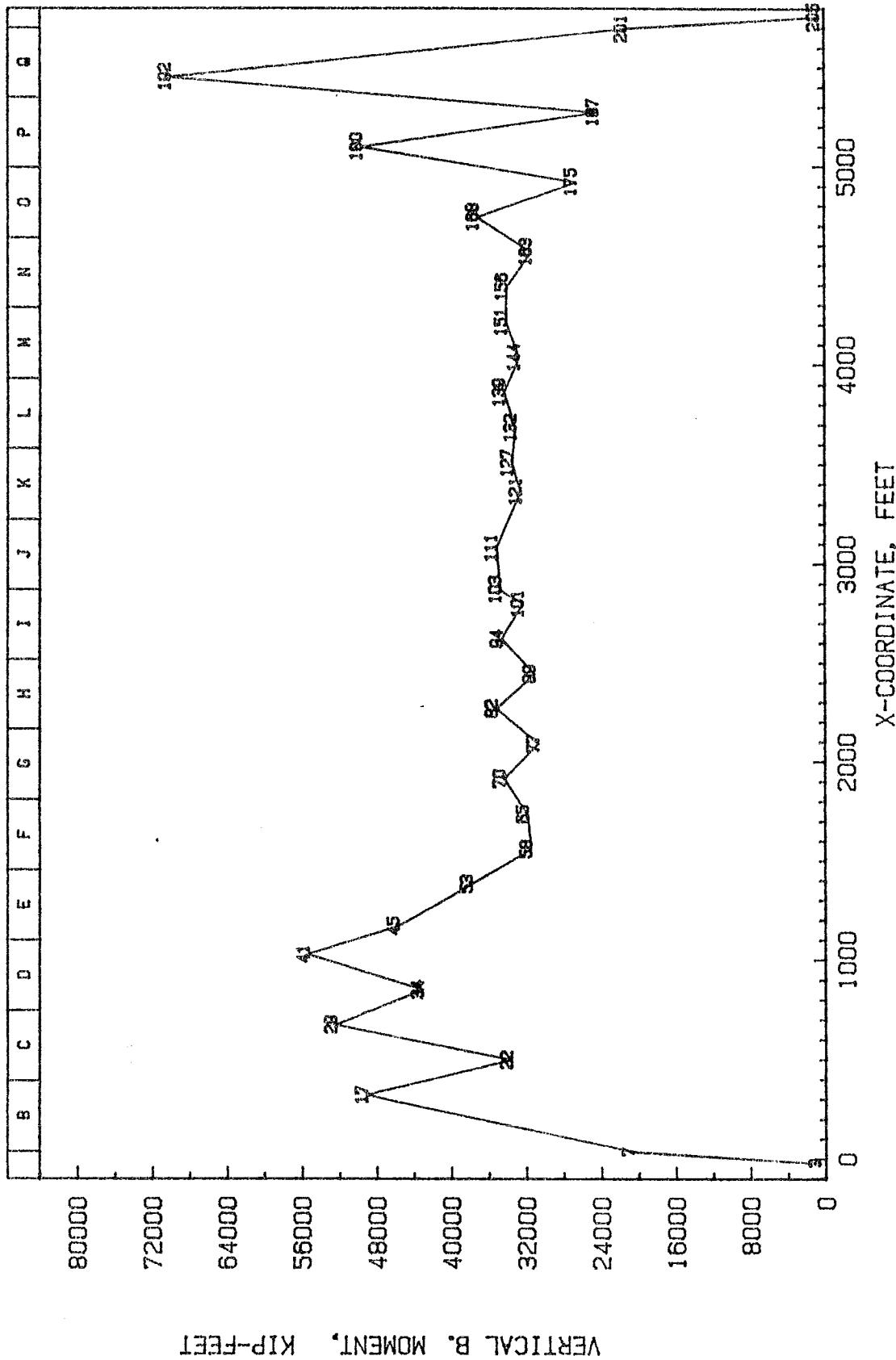
TABLE 15-16  
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SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

TORSION (KIP-FEET)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	8.783E+002	1.757E+003	2.240E+003	3.330E+003	3.826E+003
7	1.603E+003	3.206E+003	4.087E+003	6.075E+003	6.981E+003
17	2.155E+003	4.309E+003	5.494E+003	8.163E+003	9.382E+003
22	2.396E+003	4.791E+003	6.109E+003	9.069E+003	1.043E+004
29	2.549E+003	5.098E+003	6.501E+003	9.643E+003	1.109E+004
34	2.958E+003	5.916E+003	7.542E+003	1.117E+004	1.285E+004
41	2.684E+003	5.367E+003	6.843E+003	1.013E+004	1.165E+004
45	2.680E+003	5.361E+003	6.835E+003	1.011E+004	1.163E+004
53	2.601E+003	5.202E+003	6.633E+003	9.801E+003	1.128E+004
58	2.475E+003	4.950E+003	6.312E+003	9.319E+003	1.073E+004
65	2.300E+003	4.601E+003	5.866E+003	8.655E+003	9.964E+003
70	2.086E+003	4.171E+003	5.318E+003	7.846E+003	9.033E+003
77	1.851E+003	3.702E+003	4.721E+003	6.969E+003	8.022E+003
82	1.611E+003	3.222E+003	4.108E+003	6.077E+003	6.991E+003
89	1.393E+003	2.786E+003	3.552E+003	5.274E+003	6.063E+003
94	1.210E+003	2.421E+003	3.087E+003	4.605E+003	5.287E+003
101	1.097E+003	2.194E+003	2.797E+003	4.192E+003	4.807E+003
103	1.118E+003	2.237E+003	2.852E+003	4.275E+003	4.902E+003
111	1.091E+003	2.183E+003	2.783E+003	4.174E+003	4.786E+003
121	1.298E+003	2.596E+003	3.310E+003	4.935E+003	5.667E+003
127	1.453E+003	2.905E+003	3.704E+003	5.504E+003	6.325E+003
132	1.669E+003	3.338E+003	4.256E+003	6.300E+003	7.247E+003
139	1.888E+003	3.777E+003	4.815E+003	7.112E+003	8.185E+003
144	2.100E+003	4.200E+003	5.355E+003	7.900E+003	9.095E+003
151	2.290E+003	4.580E+003	5.840E+003	8.613E+003	9.917E+003
156	2.449E+003	4.898E+003	6.244E+003	9.215E+003	1.061E+004
163	2.562E+003	5.124E+003	6.533E+003	9.650E+003	1.111E+004
168	2.619E+003	5.237E+003	6.678E+003	9.873E+003	1.136E+004
175	2.605E+003	5.210E+003	6.642E+003	9.829E+003	1.131E+004
180	2.504E+003	5.008E+003	6.385E+003	9.454E+003	1.087E+004
187	2.303E+003	4.607E+003	5.874E+003	8.701E+003	1.001E+004
192	2.016E+003	4.033E+003	5.142E+003	7.619E+003	8.763E+003
201	1.457E+003	2.915E+003	3.716E+003	5.508E+003	6.334E+003
205	7.887E+002	1.577E+003	2.011E+003	2.984E+003	3.431E+003

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 10 MAY 1983

FIGURE 15-17

FIGURE 15-17

TABLE 15-18

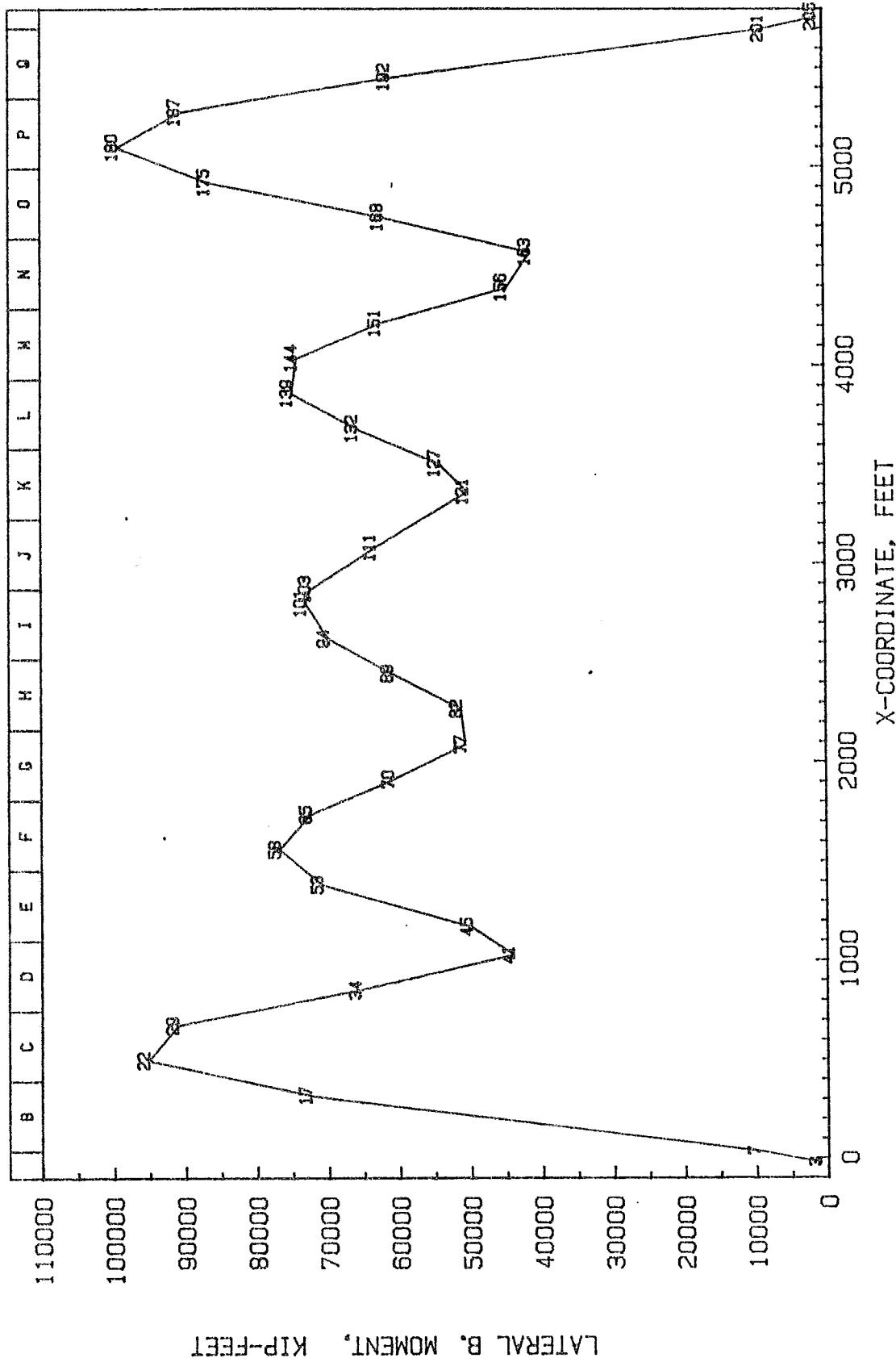
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SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## VERTICAL B. MOMENT (KIP-FEET)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.517E+002	3.034E+002	3.869E+002	5.818E+002	6.667E+002
7	4.711E+003	9.422E+003	1.201E+004	1.800E+004	2.064E+004
17	1.129E+004	2.257E+004	2.878E+004	4.277E+004	4.915E+004
22	7.640E+003	1.528E+004	1.948E+004	2.936E+004	3.363E+004
29	1.202E+004	2.404E+004	3.066E+004	4.567E+004	5.245E+004
34	9.857E+003	1.971E+004	2.514E+004	3.762E+004	4.316E+004
41	1.262E+004	2.525E+004	3.219E+004	4.833E+004	5.540E+004
45	1.049E+004	2.099E+004	2.676E+004	3.979E+004	4.572E+004
53	8.617E+003	1.723E+004	2.197E+004	3.303E+004	3.786E+004
58	7.217E+003	1.443E+004	1.840E+004	2.744E+004	3.151E+004
65	7.272E+003	1.454E+004	1.854E+004	2.780E+004	3.188E+004
70	7.855E+003	1.571E+004	2.003E+004	2.997E+004	3.438E+004
77	7.023E+003	1.405E+004	1.791E+004	2.680E+004	3.075E+004
82	8.043E+003	1.609E+004	2.051E+004	3.071E+004	3.523E+004
89	7.117E+003	1.423E+004	1.815E+004	2.716E+004	3.116E+004
94	7.917E+003	1.583E+004	2.019E+004	3.023E+004	3.467E+004
101	7.400E+003	1.480E+004	1.887E+004	2.825E+004	3.241E+004
103	7.953E+003	1.591E+004	2.028E+004	3.037E+004	3.484E+004
111	8.048E+003	1.610E+004	2.052E+004	3.072E+004	3.524E+004
121	7.452E+003	1.490E+004	1.900E+004	2.846E+004	3.264E+004
127	7.661E+003	1.532E+004	1.953E+004	2.924E+004	3.354E+004
132	7.582E+003	1.516E+004	1.933E+004	2.894E+004	3.320E+004
139	7.855E+003	1.571E+004	2.003E+004	3.001E+004	3.442E+004
144	7.508E+003	1.502E+004	1.914E+004	2.861E+004	3.283E+004
151	7.796E+003	1.559E+004	1.988E+004	2.981E+004	3.419E+004
156	7.804E+003	1.561E+004	1.990E+004	2.974E+004	3.413E+004
163	7.199E+003	1.440E+004	1.836E+004	2.749E+004	3.154E+004
168	8.497E+003	1.699E+004	2.167E+004	3.246E+004	3.723E+004
175	6.123E+003	1.225E+004	1.561E+004	2.322E+004	2.668E+004
180	1.133E+004	2.266E+004	2.889E+004	4.337E+004	4.972E+004
187	5.595E+003	1.119E+004	1.427E+004	2.119E+004	2.435E+004
192	1.602E+004	3.205E+004	4.086E+004	6.118E+004	7.018E+004
201	4.851E+003	9.703E+003	1.237E+004	1.857E+004	2.129E+004
205	1.416E+002	2.833E+002	3.612E+002	5.436E+002	6.228E+002

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, INC.  
 10 MAY 1983

FIGURE 15-19

FIGURE 15-19

TABLE 15-20

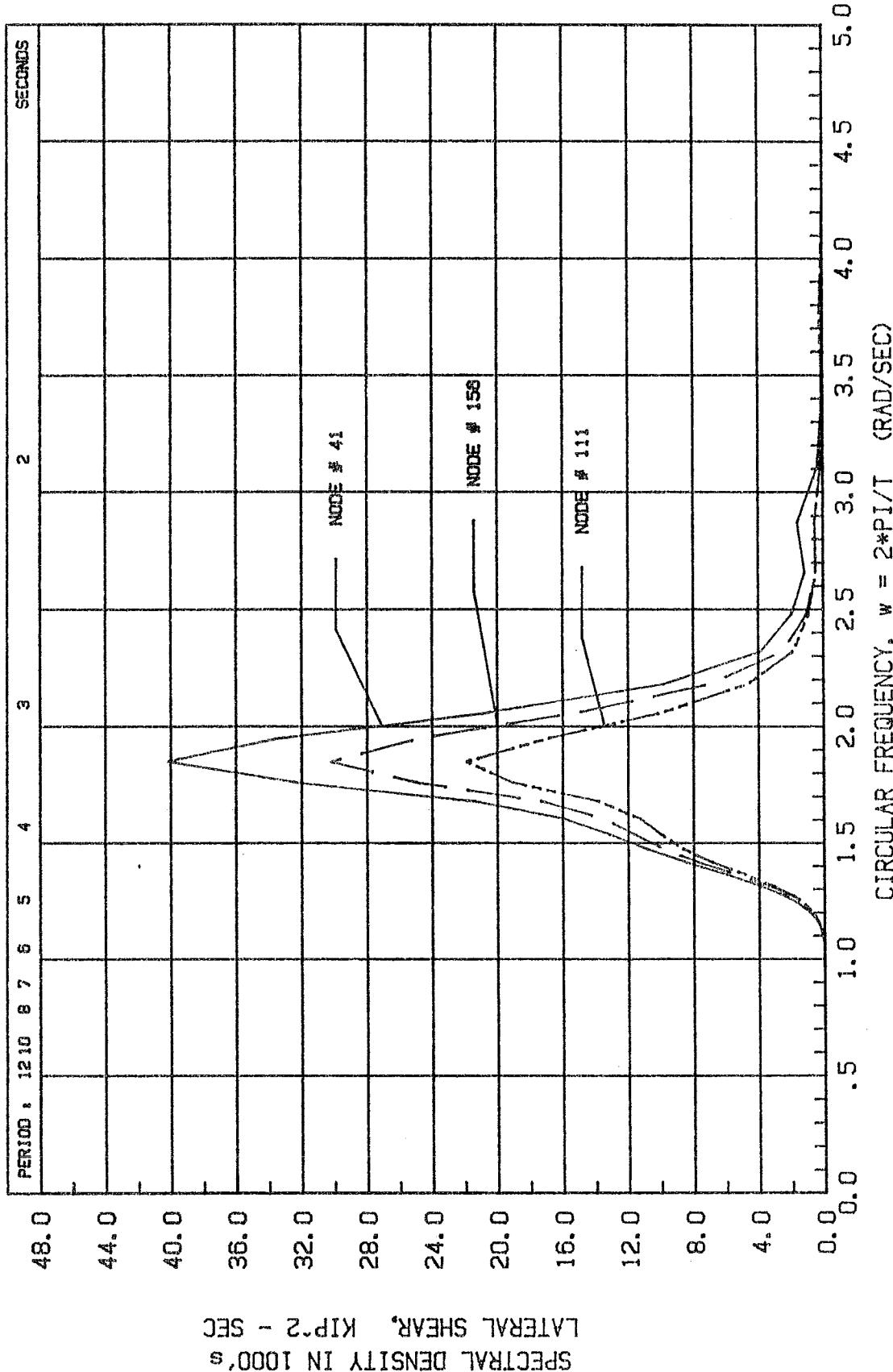
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SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 NODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## LATERAL B. MOMENT (KIP-FEET)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.717E+002	5.435E+002	6.929E+002	1.035E+003	1.188E+003
7	2.240E+003	4.481E+003	5.713E+003	8.515E+003	9.778E+003
17	1.667E+004	3.334E+004	4.251E+004	6.324E+004	7.266E+004
22	2.187E+004	4.375E+004	5.578E+004	8.284E+004	9.522E+004
29	2.098E+004	4.195E+004	5.349E+004	7.925E+004	9.114E+004
34	1.512E+004	3.023E+004	3.855E+004	5.696E+004	6.555E+004
41	1.010E+004	2.021E+004	2.577E+004	3.833E+004	4.404E+004
45	1.141E+004	2.282E+004	2.910E+004	4.352E+004	4.994E+004
53	1.625E+004	3.250E+004	4.143E+004	6.170E+004	7.088E+004
58	1.765E+004	3.529E+004	4.500E+004	6.679E+004	7.678E+004
65	1.666E+004	3.333E+004	4.249E+004	6.295E+004	7.240E+004
70	1.399E+004	2.797E+004	3.567E+004	5.287E+004	6.080E+004
77	1.161E+004	2.322E+004	2.961E+004	4.406E+004	5.062E+004
82	1.173E+004	2.347E+004	2.992E+004	4.459E+004	5.121E+004
89	1.397E+004	2.794E+004	3.563E+004	5.298E+004	6.087E+004
94	1.606E+004	3.212E+004	4.095E+004	6.076E+004	6.985E+004
101	1.680E+004	3.360E+004	4.284E+004	6.353E+004	7.305E+004
103	1.665E+004	3.331E+004	4.246E+004	6.298E+004	7.241E+004
111	1.453E+004	2.905E+004	3.704E+004	5.504E+004	6.326E+004
121	1.151E+004	2.301E+004	2.934E+004	4.372E+004	5.021E+004
127	1.244E+004	2.487E+004	3.171E+004	4.714E+004	5.417E+004
132	1.513E+004	3.026E+004	3.859E+004	5.720E+004	6.577E+004
139	1.722E+004	3.445E+004	4.392E+004	6.508E+004	7.484E+004
144	1.706E+004	3.412E+004	4.350E+004	6.457E+004	7.423E+004
151	1.432E+004	2.863E+004	3.651E+004	5.438E+004	6.246E+004
156	1.021E+004	2.043E+004	2.604E+004	3.893E+004	4.468E+004
163	9.489E+003	1.898E+004	2.420E+004	3.594E+004	4.131E+004
168	1.430E+004	2.860E+004	3.647E+004	5.393E+004	6.205E+004
175	1.989E+004	3.977E+004	5.071E+004	7.513E+004	8.641E+004
180	2.281E+004	4.561E+004	5.815E+004	8.636E+004	9.926E+004
187	2.077E+004	4.154E+004	5.296E+004	7.877E+004	9.050E+004
192	1.399E+004	2.799E+004	3.569E+004	5.314E+004	6.104E+004
201	1.911E+003	3.822E+003	4.873E+003	7.267E+003	8.344E+003
205	2.070E+002	4.141E+002	5.279E+002	7.889E+002	9.054E+002

# NEW I-90 BRIDGE



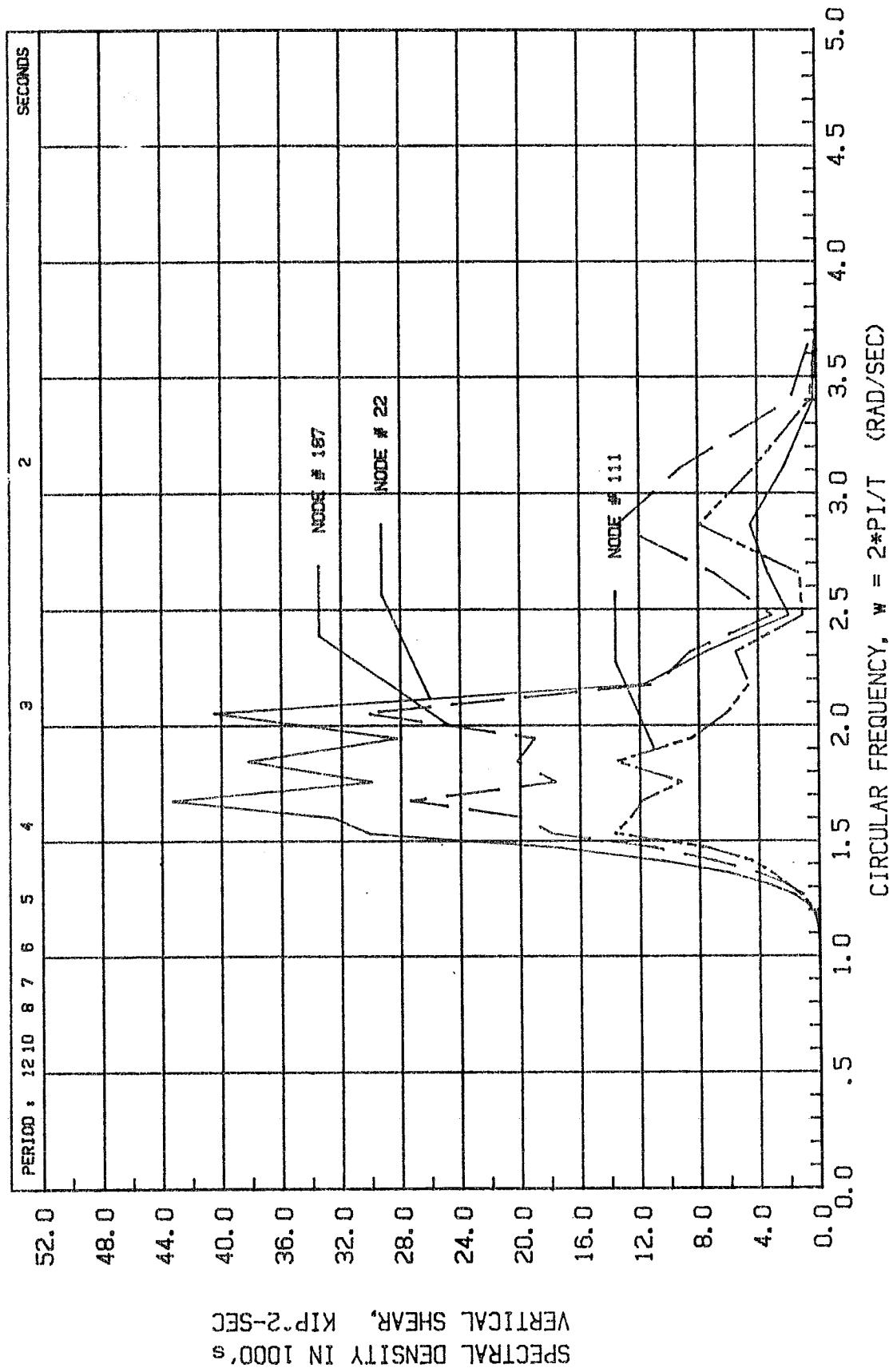
SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 80.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERIC STRUCTURAL DAMPING = 2%

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FIGURE 15-21

FIGURE 15-21

NEW T-CO BRIDGE



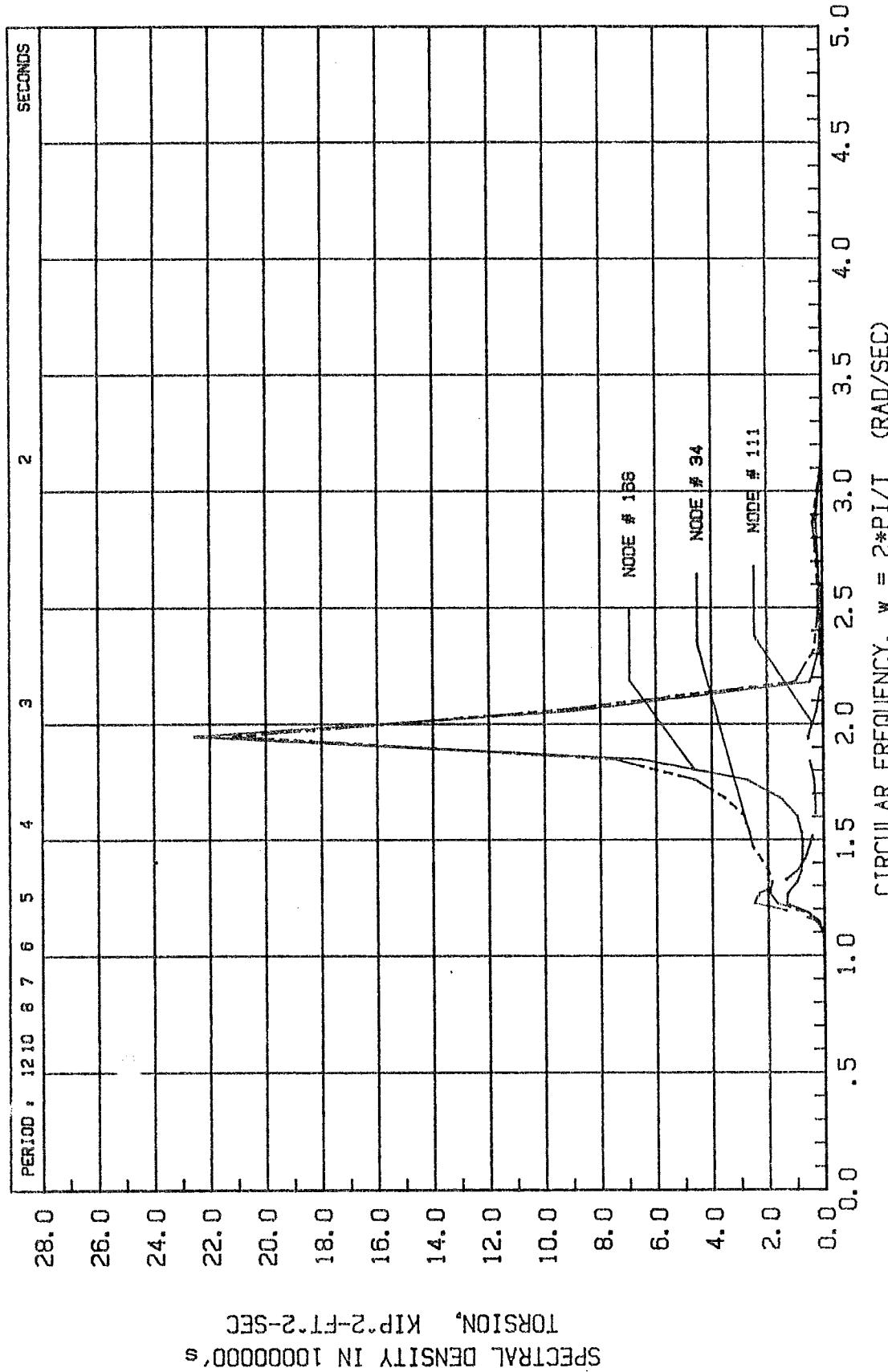
SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-22

FIGURE 15-22

# NEW I-90 BRIDGE



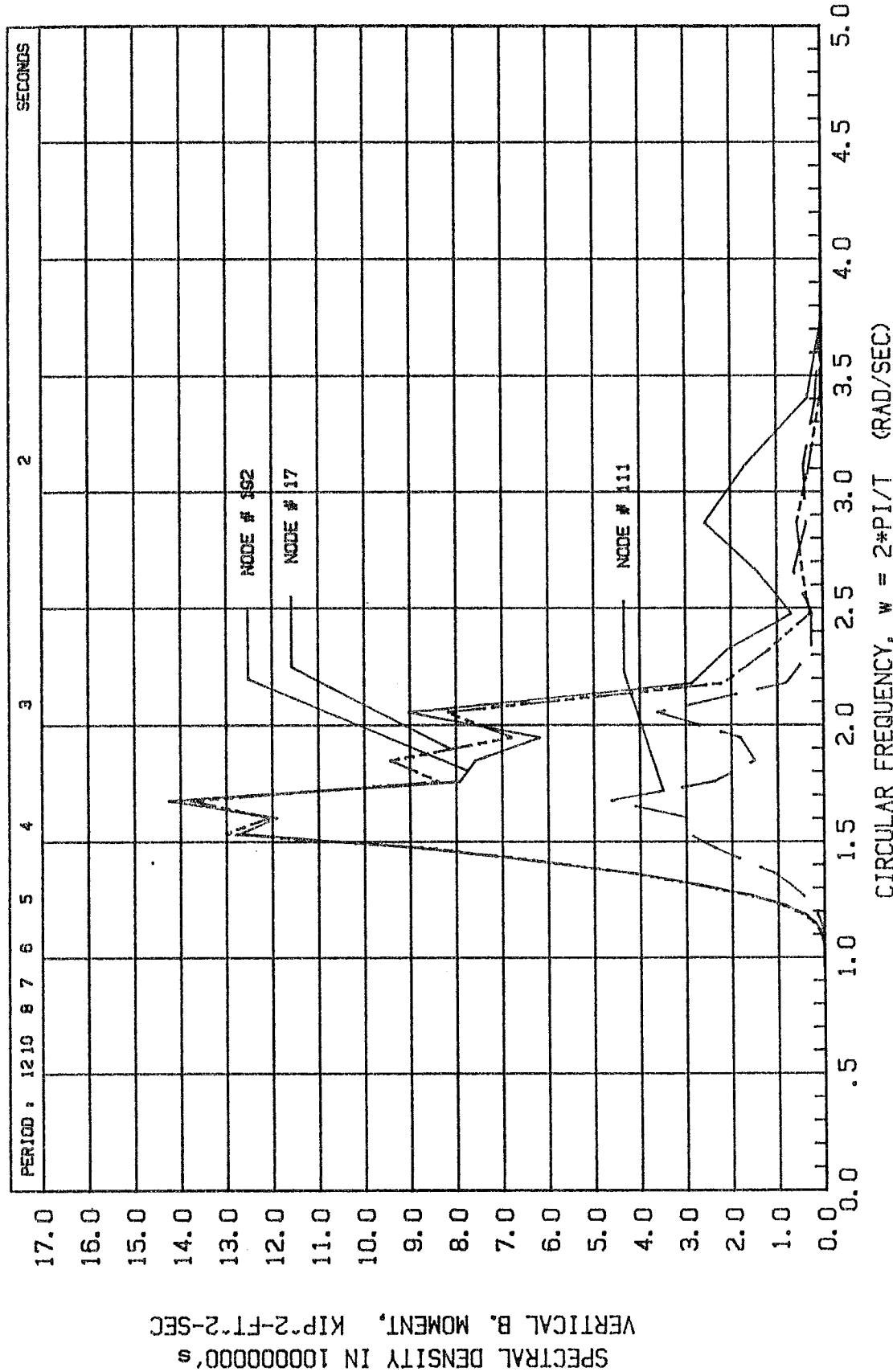
SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-23

FIGURE 15-23

# NEW I-90 BRIDGE

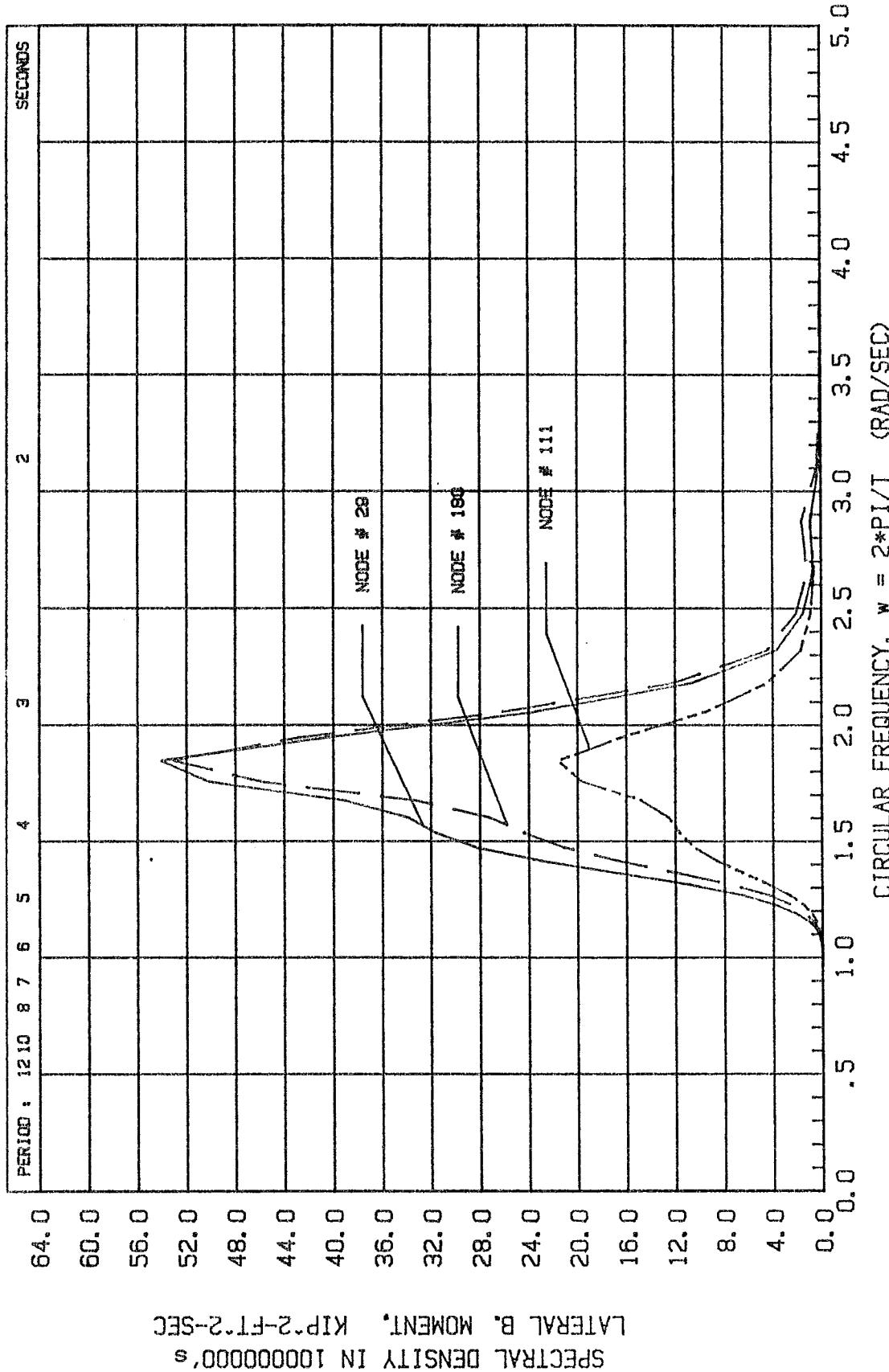


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FIGURE 15-24

FIGURE 15-24

# NEW I-90 BRIDGE

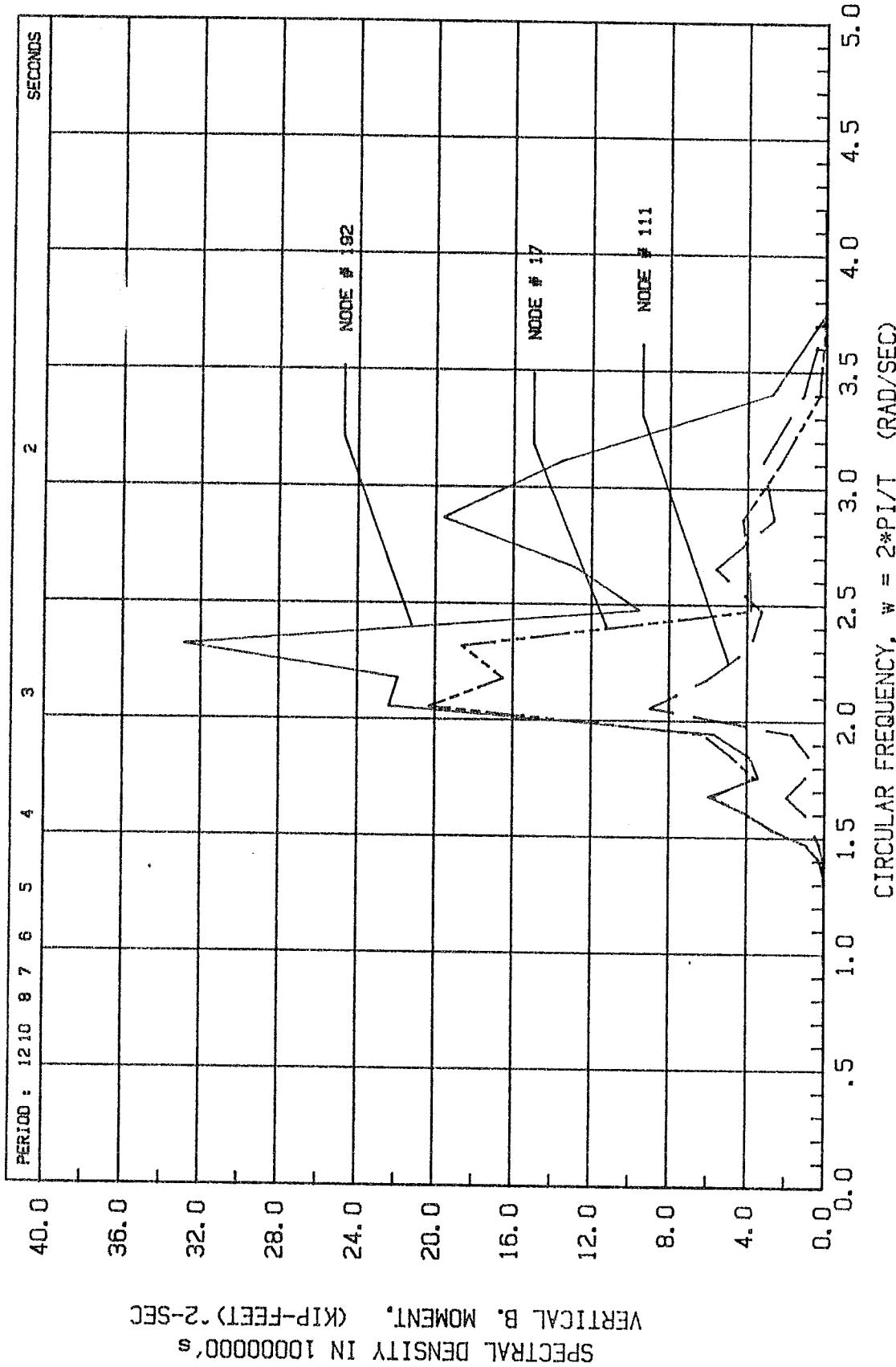


SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

FIGURE 15-25

FIGURE 15-25

# NEW T-SO BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET      MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH )  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

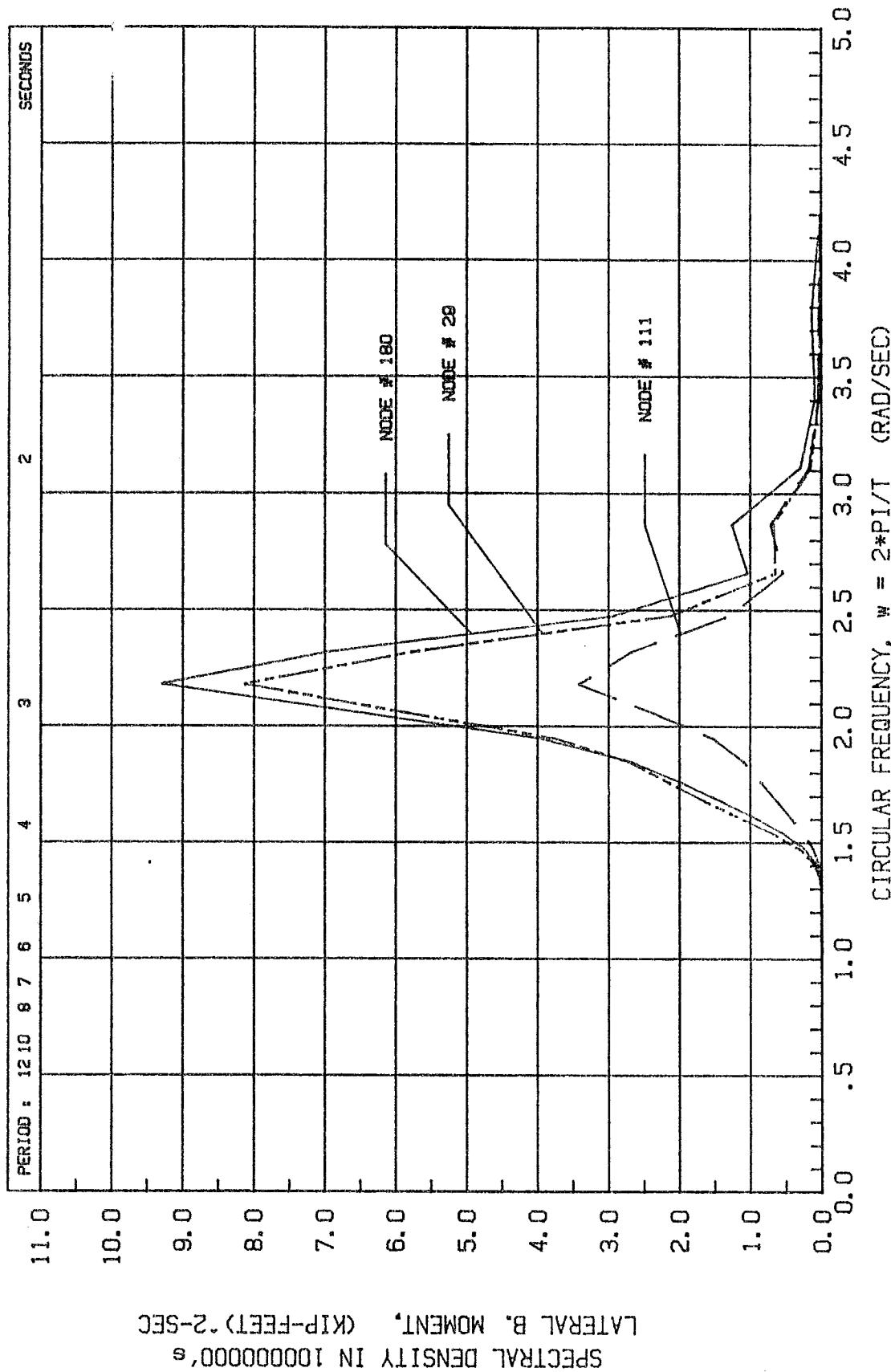
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FIGURE 15-26

FIGURE 15-26

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 2.15 FEET   MODAL PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES < WIND FROM SOUTH >  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-27

FIGURE 15-27

## 15.2 Concurrent Load Responses

Data are presented in Tables 15-28 through 15-32 for developing combined loading conditions, in the 100 year storm condition at the following locations of particular structural interest:

Nodes 7 and 201, the connections of the cross pontoons to the remainder of the bridge at the West and East ends, respectively.

Nodes 34 and 192, the discontinuities between typical pontoon section and the beginning of elevated, column-supported roadway at the West and East ends, respectively.

Node 89, representing a typical case near the middle of the bridge.

This information is presented two different ways in each table: the phase cofactor matrix and the folded cross co-spectral moment matrix. The more familiar cofactor presentation, provides a limited view of combined response processes. For instance we know the maxima of the lateral and vertical bending processes as defined by our original choice of orthogonal y- and z-axes. But the capacities of the structure in these two degrees of freedom are clearly interrelated. The phase cofactors permit us to compute two particular cases from among possible maxima of combined response processes, for comparison with the structural capacity. The two cases are the probable concurrent values of each process at the instant when each of the associated processes are at a maximum. The cofactors take on useful meaning only when discussing extreme levels of response.

The presentation convention for cofactor matrices is as follows: for two processes  $x_1$  and  $x_2$ , the cofactor matrix is

$$\begin{vmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{vmatrix}$$

The values of  $C_{11}$  and  $C_{22}$  are unity.  $C_{12}$  is the proportion of the maximum of process  $x_1$  most likely to occur when process  $x_2$  is maximum.  $C_{21}$  is the proportion of maximum  $x_2$  most likely to occur when  $x_1$  is maximum.

The physical significance of the cofactors will be further developed by an example.

A more comprehensive description of combined processes can be developed by use of the folded cross co-spectral moment matrices, as described in Ref. [1], for any new process which can be defined as a linear combination of known processes. For instance, this new process could be a combined stress in some element of the structure, or it could be a load response defined in some new coordinate system.

Returning to the example of combined bending discussed above, the axial stress at one corner of the bridge cross section may be related to the vertical and lateral moments by two linear combination coefficients (in this case, reciprocals of the two respective section modulii). Or, a new moment process could be defined for an axis passing through the corner of the cross section. In any event, a set of linear combination coefficient products  $C_{ij}$ , multiplied by the respective elements of the zero order co-spectral moment matrix  $m_{ij}^{(0)}$  and summed, will yield the zero order moment of the new process  $m^{(0)}$ . The root mean square response of the new process is the square root of this value, and other statical representations of averages and extremes may be obtained in the conventional manner.

In the following example, combined vertical and lateral bending information is developed for node 89, using the data in Table 15-30. To avoid introducing structural properties into the analysis, the example considers bending in a series of new planes, obtained by rotating in  $15^\circ$  increments from the xy-plane (lateral bending) to the xz-plane (vertical bending). The capacities of the structure in each of these planes could of course be computed, but only the loads are presented here.

The linear combination coefficients for the first quadrant are  $C_1 = \cos \theta$  and  $C_2 = +\sin \theta$ . Using the co-spectral moment data, the zero-order moment of the new process is:

$$m = m_{11} C_1^2 + m_{12} C_1 C_2 + m_{22} C_2^2$$

$$\text{rms response} = \sqrt{m}$$

$$\text{expected maximum response} = 4.30 \times \text{rms}$$

$$m_{11} = 1.14 \text{ E9}$$

$$m_{12} = -1.01 \text{ E7}$$

$$m_{22} = 2.08 \text{ E8}$$

[1] A Note on the Application of Response Cross Spectra, Bruce L. Hutchison, Journal of Ship Research, June 1982

The calculation of the response process for bending in each plane is as follows:

	$C_{11}$	$C_{12}$	$C_{22}$	$m$	rms	ex. max.
0	1	0	0	1.14E9	3.38E4	1.45E5
15	.93	.25	.07	1.07E9	2.17E4	1.41E5
30	.75	.43	.25	9.27E8	3.04E4	1.31E5
45	.50	.50	.50	6.69E8	2.59E4	1.11E5
60	.25	.43	.75	4.37E8	2.09E4	8.99E4
75	.07	.25	.93	2.71E8	1.65E4	7.08E4
90	0	0	1	2.08E8	1.44E4	6.20E4

The combined bending moment, projected into each of these planes, when lateral or vertical moment are maximum, is determined from the cofactors. When lateral bending moment,  $M_1$  is maximum:

$$\max \quad M_1 = 1.45E5$$

$$\max \quad M_2 = 6.20E4$$

$$C_{21} = .0620$$

$$M(\theta) = M_1 \cos \theta + C_{21} M_2 \sin \theta$$

Similarly, when vertical bending  $M_2$  is maximum

$$C_{12} = .0229$$

$$M(\theta) = C_{12} M_1 \cos \theta + M_2 \sin \theta$$

<u><math>\theta</math></u>	$M(\theta)$ when $M_1$ is max	$M(\theta)$ when $M_2$ is max
0	1.45E5	4.21E3
15	1.41E5	1.93E4
30	1.28E5	3.39E4
45	1.05E5	4.62E4
60	7.58E4	5.58E4
75	4.12E4	6.07E4
90	3.84E3	6.20E4

The three sets of values obtained for the bending process in the various planes are plotted, in an  $M_1 - M_2$  phase plane representation in figure 15-33. It is evident that the co-spectral moment matrix provides more useful information in this case.

TABLE 15-28

\*\*\*\*\*

NODE #7

## FOLDED CROSS CO-SPECTRAL MOMENT MATRIX

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	2.48E+004	9.15E+002	-1.29E+005	-----	-----
LATERAL SHEAR	-----	9.75E+003	-9.60E+004	-----	-----
TORSIONAL MOMENT	-----	-----	1.66E+007	-----	-----
LATERAL B. MOMENT	-----	-----	-----	2.26E+007	-3.57E+006
VERTICAL B. MOMENT	-----	-----	-----	-----	6.98E+007

## TABLE OF CO-FACTORS

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.0000000	-.0325063	-.1360109	-----	-----
LATERAL SHEAR	-.1171604	1.0000000	-.0084763	-----	-----
TORSIONAL MOMENT	-.3027691	.1231294	1.0000000	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.0000000	.0740149
VERTICAL B. MOMENT	-----	-----	-----	-.0222742	1.0000000

TABLE 15-29  
 \*\*\*\*  
 NODE #34  
 FOLDED CROSS CO-SPECTRAL MOMENT MATRIX

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.39E+004	-2.50E+003	-4.24E+003	-----	-----
LATERAL SHEAR	-----	1.52E+004	-5.15E+005	-----	-----
TORSIONAL MOMENT	-----	-----	6.10E+007	-----	-----
LATERAL B. MOMENT	-----	-----	-----	2.26E+009	1.19E+008
VERTICAL B. MOMENT	-----	-----	-----	-----	7.88E+008

TABLE OF CO-FACTORS

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.0000000	-.2195744	-.0469826	-----	-----
LATERAL SHEAR	-.1924634	1.0000000	-.2670310	-----	-----
TORSIONAL MOMENT	.0050244	-.2106862	1.0000000	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.0000000	-.0550301
VERTICAL B. MOMENT	-----	-----	-----	.0696912	1.0000000

TABLE 15-30

\*\*\*\*\*

NODE #89

## FOLDED CROSS CO-SPECTRAL MOMENT MATRIX

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.41E+004	-1.54E+003	-4.83E+003	-----	-----
LATERAL SHEAR	-----	1.17E+004	-2.30E+004	-----	-----
TORSIONAL MOMENT	-----	-----	1.62E+007	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.14E+009	-1.01E+007
VERTICAL B. MOMENT	-----	-----	-----	-----	2.08E+008

## TABLE OF CO-FACTORS

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.0000000	-.2496029	-.0835097	-----	-----
LATERAL SHEAR	-.1541428	1.0000000	.1300401	-----	-----
TORSIONAL MOMENT	-.0442699	.0809028	1.0000000	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.0000000	.0229090
VERTICAL B. MOMENT	-----	-----	-----	.0620135	1.0000000

TABLE 15-31  
\*\*\*\*\*  
NODE #192

FOLDED CROSS CO-SPECTRAL MOMENT MATRIX

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	3.97E+003	-1.34E+003	-1.02E+005	-----	-----
LATERAL SHEAR	-----	1.40E+004	-2.20E+005	-----	-----
TORSIONAL MOMENT	-----	-----	2.82E+007	-----	-----
LATERAL B. MOMENT	-----	-----	-----	9.13E+008	-1.02E+008
VERTICAL B. MOMENT	-----	-----	-----	-----	9.41E+008

TABLE OF CO-FACTORS

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.0000000	-.2655262	-.1263650	-----	-----
LATERAL SHEAR	-.2093446	1.0000000	-.0122177	-----	-----
TORSIONAL MOMENT	-.2101162	.0116363	1.0000000	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.0000000	.0126989
VERTICAL B. MOMENT	-----	-----	-----	.0309269	1.0000000

TABLE 15-32

\*\*\*\*\*

NODE #201

## FOLDED CROSS CO-SPECTRAL MOMENT MATRIX

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	2.29E+004	8.96E+002	-9.41E+003	-----	-----
LATERAL SHEAR	-----	7.10E+003	-8.62E+004	-----	-----
TORSIONAL MOMENT	-----	-----	1.44E+007	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.51E+007	-2.97E+006
VERTICAL B. MOMENT	-----	-----	-----	-----	5.72E+007

## TABLE OF CO-FACTORS

	VERTICAL SHEAR	LATERAL SHEAR	TORSION MOMENT	LATERAL B. MOMENT	VERTICAL B. MOMENT
VERTICAL SHEAR	1.0000000	-.0270500	-.0431957	-----	-----
LATERAL SHEAR	-.0281384	1.0000000	.0985008	-----	-----
TORSIONAL MOMENT	-.2362236	.1667661	1.0000000	-----	-----
LATERAL B. MOMENT	-----	-----	-----	1.0000000	.0040928
VERTICAL B. MOMENT	-----	-----	-----	-.0404879	1.0000000

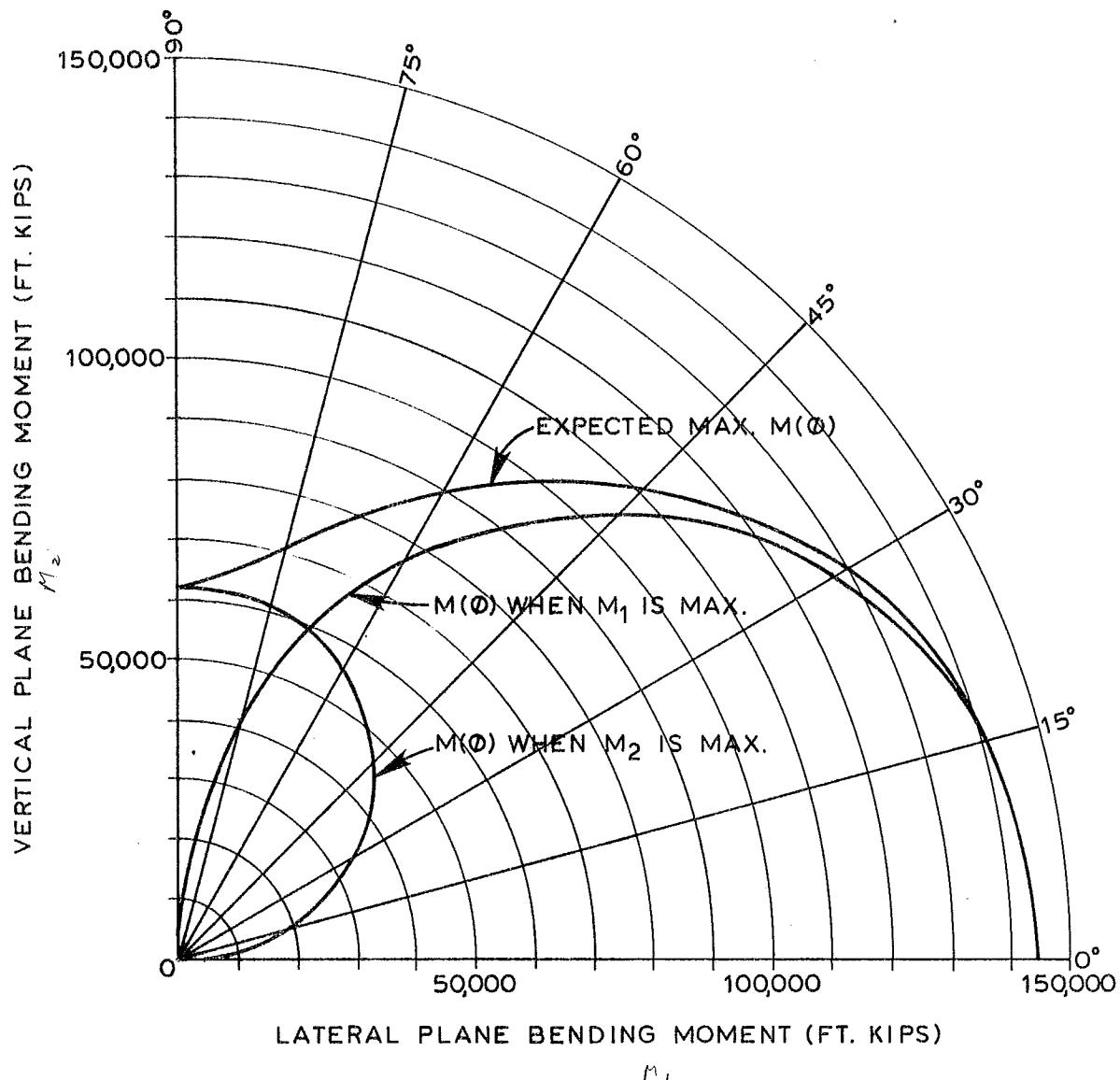


FIG. 15-33

PHASE PLANE REPRESENTATION OF  
COMBINED BENDING PROCESSES, NODE 89

### 15.3 Motion Responses

Bridge motion and higher order time derivatives (acceleration and jerk) are presented for selected locations. These values are of interest for several purposes:

(1) design of the transfer span bearings, which must accommodate the expected maximum dynamic motions in addition to static excursions, and

(2) As a measure of motorist comfort and safety. Analytical results for the two existing bridges (in Volumes III and IV of this report) together with subjective experience on these structures in storm conditions, will provide a comparative basis for judging the motion response characteristics of the new design.

Five degree of freedom motion response statistics (for sway, heave, roll, pitch and yaw) at selected nodes have been transformed to appropriate vertical locations and tabulated as follows:

<u>From node</u>	<u>To vertical location</u>	
	<u>Z, above DWL</u>	<u>relative to roadway</u>
3	36.80 ft	At span bearings
65	10.20 ft	3 ft above
101	10.20 ft	3 ft above
156	10.20 ft	2 ft above
206	10.72 ft	At span bearings

<u>Motion response statistics for:</u>	<u>Given in Table</u>	
	<u>100 yr storm</u>	<u>1 yr storm</u>
Sway	15-34	15-39
Heave	15-35	15-40
Roll	15-36	15-41
Pitch	15-37	15-42
Yaw	15-38	15-43

Example motion spectra, for in 100 year storm conditions, are shown in figures 15-44 through 15-52.

TABLE 15-34

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## SWAY (FEET)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	8.781E-002	1.756E-001	2.239E-001	3.255E-001	3.761E-001
65	6.944E-002	1.389E-001	1.771E-001	2.583E-001	2.982E-001
101	5.842E-002	1.168E-001	1.490E-001	2.177E-001	2.512E-001
156	5.591E-002	1.118E-001	1.426E-001	2.073E-001	2.395E-001
205	8.546E-002	1.709E-001	2.179E-001	3.169E-001	3.662E-001

## SWAY ACCELERATION (FT/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.631E-001	5.262E-001	6.709E-001	9.833E-001	1.134E+000
65	2.254E-001	4.508E-001	5.748E-001	8.439E-001	9.727E-001
101	2.004E-001	4.007E-001	5.110E-001	7.523E-001	8.665E-001
156	1.695E-001	3.390E-001	4.322E-001	6.361E-001	7.327E-001
205	2.586E-001	5.172E-001	6.594E-001	9.670E-001	1.115E+000

## SWAY JERK (FT/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	4.962E-001	9.924E-001	1.265E+000	1.865E+000	2.147E+000
65	4.351E-001	8.702E-001	1.109E+000	1.637E+000	1.884E+000
101	4.026E-001	8.053E-001	1.027E+000	1.521E+000	1.749E+000
156	3.380E-001	6.760E-001	8.619E-001	1.283E+000	1.474E+000
205	4.913E-001	9.826E-001	1.253E+000	1.849E+000	2.128E+000

TABLE 15-35  
\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

**HEAVE (FEET)**

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	3.787E-002	7.575E-002	9.658E-002	1.411E-001	1.629E-001
65	5.270E-002	1.054E-001	1.344E-001	1.954E-001	2.258E-001
101	5.353E-002	1.071E-001	1.365E-001	1.983E-001	2.292E-001
156	5.553E-002	1.111E-001	1.416E-001	2.055E-001	2.376E-001
205	3.741E-002	7.481E-002	9.538E-002	1.392E-001	1.607E-001

**HEAVE ACCELERATION (FT/SEC^2)**

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.310E-001	2.620E-001	3.340E-001	4.926E-001	5.672E-001
65	1.675E-001	3.350E-001	4.272E-001	6.328E-001	7.277E-001
101	1.651E-001	3.303E-001	4.211E-001	6.229E-001	7.166E-001
156	1.658E-001	3.316E-001	4.228E-001	6.242E-001	7.185E-001
205	1.284E-001	2.567E-001	3.273E-001	4.840E-001	5.569E-001

**HEAVE JERK (FT/SEC^3)**

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.690E-001	5.381E-001	6.861E-001	1.018E+000	1.171E+000
65	3.665E-001	7.330E-001	9.346E-001	1.398E+000	1.604E+000
101	3.541E-001	7.082E-001	9.030E-001	1.351E+000	1.550E+000
156	3.460E-001	6.920E-001	8.823E-001	1.316E+000	1.511E+000
205	2.737E-001	5.474E-001	6.979E-001	1.040E+000	1.195E+000

TABLE 15-36

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## ROLL (RADIAN)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	6.906E-004	1.381E-003	1.761E-003	2.556E-003	2.955E-003
65	5.447E-004	1.089E-003	1.389E-003	2.034E-003	2.346E-003
101	1.123E-003	2.246E-003	2.863E-003	4.202E-003	4.844E-003
156	7.556E-004	1.511E-003	1.927E-003	2.777E-003	3.215E-003
205	1.140E-003	2.279E-003	2.906E-003	4.208E-003	4.867E-003

## ROLL ACCELERATION (RAD/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.035E-003	4.069E-003	5.188E-003	7.613E-003	8.776E-003
65	2.006E-003	4.012E-003	5.116E-003	7.557E-003	8.697E-003
101	4.215E-003	8.430E-003	1.075E-002	1.581E-002	1.821E-002
156	1.879E-003	3.758E-003	4.792E-003	7.036E-003	8.110E-003
205	3.156E-003	6.311E-003	8.047E-003	1.178E-002	1.359E-002

## ROLL JERK (RAD/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	3.894E-003	7.708E-003	9.930E-003	1.464E-002	1.686E-002
65	4.223E-003	8.446E-003	1.077E-002	1.601E-002	1.839E-002
101	8.338E-003	1.668E-002	2.126E-002	3.132E-002	3.607E-002
156	3.629E-003	7.258E-003	9.254E-003	1.376E-002	1.581E-002
205	5.848E-003	1.170E-002	1.491E-002	2.192E-002	2.526E-002

TABLE 15-37

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## PITCH (RADIAN)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	3.892E-004	7.783E-004	9.924E-004	1.451E-003	1.674E-003
65	3.292E-004	6.583E-004	8.394E-004	1.226E-003	1.415E-003
101	3.239E-004	6.479E-004	8.260E-004	1.209E-003	1.394E-003
156	3.289E-004	6.578E-004	8.387E-004	1.229E-003	1.417E-003
205	3.303E-004	6.606E-004	8.423E-004	1.232E-003	1.422E-003

## PITCH ACCELERATION (RAD/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.426E-003	2.852E-003	3.636E-003	5.404E-003	6.210E-003
65	1.204E-003	2.407E-003	3.070E-003	4.570E-003	5.250E-003
101	1.249E-003	2.498E-003	3.186E-003	4.749E-003	5.453E-003
156	1.320E-003	2.641E-003	3.367E-003	5.028E-003	5.772E-003
205	1.278E-003	2.556E-003	3.259E-003	4.865E-003	5.585E-003

## PITCH JERK (RAD/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	3.272E-003	6.543E-003	8.343E-003	1.251E-002	1.435E-002
65	2.835E-003	5.671E-003	7.230E-003	1.087E-002	1.245E-002
101	2.995E-003	5.991E-003	7.638E-003	1.147E-002	1.315E-002
156	3.245E-003	6.490E-003	8.275E-003	1.245E-002	1.427E-002
205	3.121E-003	6.241E-003	7.958E-003	1.197E-002	1.372E-002

TABLE 15-38

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## YAW (RADIAN)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.648E-004	5.296E-004	6.752E-004	9.854E-004	1.138E-003
65	1.132E-004	2.265E-004	2.988E-004	4.209E-004	4.860E-004
101	1.421E-004	2.841E-004	3.623E-004	5.272E-004	6.090E-004
156	1.633E-004	3.267E-004	4.165E-004	6.086E-004	7.023E-004
205	2.468E-004	4.935E-004	6.293E-004	9.187E-004	1.060E-003

## YAW ACCELERATION (RAD/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	8.835E-004	1.767E-003	2.253E-003	3.319E-003	3.823E-003
65	3.756E-004	7.512E-004	9.578E-004	1.418E-003	1.631E-003
101	4.420E-004	8.841E-004	1.127E-003	1.660E-003	1.912E-003
156	5.556E-004	1.111E-003	1.417E-003	2.083E-003	2.400E-003
205	8.330E-004	1.666E-003	2.124E-003	3.131E-003	3.606E-003

## YAW JERK (RAD/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.792E-003	3.583E-003	4.568E-003	6.786E-003	7.799E-003
65	8.163E-004	1.633E-003	2.081E-003	3.116E-003	3.574E-003
101	8.918E-004	1.784E-003	2.274E-003	3.381E-003	3.885E-003
156	1.097E-003	2.194E-003	2.798E-003	4.132E-003	4.756E-003
205	1.702E-003	3.403E-003	4.339E-003	6.450E-003	7.412E-003

TABLE 15-39

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## SWAY (FEET)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.493E-002	4.985E-002	6.356E-002	9.389E-002	1.081E-001
65	2.352E-002	4.703E-002	5.997E-002	8.866E-002	1.020E-001
101	2.325E-002	4.651E-002	5.930E-002	8.779E-002	1.010E-001
156	1.527E-002	3.054E-002	3.893E-002	5.769E-002	6.634E-002
205	2.501E-002	5.002E-002	6.378E-002	9.427E-002	1.085E-001

## SWAY ACCELERATION (FT/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.153E-001	2.306E-001	2.940E-001	4.372E-001	5.023E-001
65	1.103E-001	2.206E-001	2.813E-001	4.181E-001	4.805E-001
101	1.130E-001	2.259E-001	2.880E-001	4.287E-001	4.925E-001
156	8.037E-002	1.607E-001	2.050E-001	3.075E-001	3.526E-001
205	1.178E-001	2.356E-001	3.004E-001	4.472E-001	5.137E-001

## SWAY JERK (FT/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.667E-001	5.333E-001	6.800E-001	1.016E+000	1.166E+000
65	2.536E-001	5.073E-001	6.468E-001	9.657E-001	1.109E+000
101	2.648E-001	5.296E-001	6.752E-001	1.010E+000	1.159E+000
156	2.118E-001	4.236E-001	5.402E-001	8.160E-001	9.340E-001
205	2.760E-001	5.520E-001	7.038E-001	1.053E+000	1.208E+000

TABLE 15-40

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## HEAVE (FEET)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.372E-002	2.744E-002	3.499E-002	5.183E-002	5.961E-002
65	1.584E-002	3.167E-002	4.038E-002	6.022E-002	6.915E-002
101	1.631E-002	3.262E-002	4.160E-002	6.189E-002	7.110E-002
156	1.728E-002	3.457E-002	4.407E-002	6.557E-002	7.533E-002
205	1.407E-002	2.815E-002	3.589E-002	5.329E-002	6.125E-002

## HEAVE ACCELERATION (FT/SEC^2)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	6.915E-002	1.383E-001	1.763E-001	2.633E-001	3.022E-001
65	9.872E-002	1.974E-001	2.517E-001	3.786E-001	4.338E-001
101	9.598E-002	1.920E-001	2.447E-001	3.679E-001	4.216E-001
156	9.972E-002	1.994E-001	2.543E-001	3.814E-001	4.373E-001
205	7.624E-002	1.525E-001	1.944E-001	2.910E-001	3.338E-001

## HEAVE JERK (FT/SEC^3)

NODE	RMS	AVERAGES		EXPECTED MAXIMA	
		SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.494E-001	3.387E-001	4.319E-001	6.478E-001	7.428E-001
65	2.695E-001	5.389E-001	6.872E-001	1.036E+000	1.187E+000
101	2.598E-001	5.195E-001	6.624E-001	9.998E-001	1.145E+000
156	2.611E-001	5.222E-001	6.658E-001	1.002E+000	1.148E+000
205	1.939E-001	3.879E-001	4.946E-001	7.434E-001	8.520E-001

TABLE 15-41

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## ROLL (RADIAN)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.774E-004	3.549E-004	4.525E-004	6.677E-004	7.686E-004
65	1.947E-004	3.895E-004	4.966E-004	7.359E-004	8.463E-004
101	4.025E-004	8.051E-004	1.026E-003	1.513E-003	1.742E-003
156	1.525E-004	3.050E-004	3.888E-004	5.771E-004	6.634E-004
205	2.654E-004	5.307E-004	6.767E-004	9.975E-004	1.149E-003

## ROLL ACCELERATION (RAD/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	7.912E-004	1.582E-003	2.018E-003	2.997E-003	3.445E-003
65	1.001E-003	2.002E-003	2.553E-003	3.817E-003	4.380E-003
101	1.705E-003	3.411E-003	4.349E-003	6.430E-003	7.398E-003
156	8.367E-004	1.673E-003	2.133E-003	3.202E-003	3.671E-003
205	1.137E-003	2.274E-003	2.899E-003	4.294E-003	4.938E-003

## ROLL JERK (RAD/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.807E-003	3.613E-003	4.607E-003	6.886E-003	7.902E-003
65	2.512E-003	5.025E-003	6.406E-003	9.633E-003	1.104E-002
101	3.633E-003	7.266E-003	9.264E-003	1.375E-002	1.580E-002
156	2.213E-003	4.426E-003	5.644E-003	8.516E-003	9.751E-003
205	2.481E-003	4.962E-003	6.327E-003	9.406E-003	1.081E-002

TABLE 15-42

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## PITCH (RADIAN)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.534E-004	3.069E-004	3.913E-004	5.829E-004	6.695E-004
65	1.392E-004	2.784E-004	3.550E-004	5.289E-004	6.074E-004
101	1.392E-004	2.784E-004	3.550E-004	5.301E-004	6.085E-004
156	1.357E-004	2.713E-004	3.459E-004	5.170E-004	5.933E-004
205	1.393E-004	2.785E-004	3.551E-004	5.306E-004	6.090E-004

## PITCH ACCELERATION (RAD/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	9.281E-004	1.856E-003	2.367E-003	3.559E-003	4.078E-003
65	8.439E-004	1.688E-003	2.152E-003	3.237E-003	3.709E-003
101	8.919E-004	1.784E-003	2.274E-003	3.422E-003	3.921E-003
156	9.035E-004	1.807E-003	2.304E-003	3.476E-003	3.980E-003
205	9.158E-004	1.832E-003	2.335E-003	3.519E-003	4.030E-003

## PITCH JERK (RAD/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	2.523E-003	5.047E-003	6.434E-003	9.713E-003	1.112E-002
65	2.309E-003	4.618E-003	5.888E-003	8.894E-003	1.018E-002
101	2.444E-003	4.889E-003	6.233E-003	9.404E-003	1.077E-002
156	2.575E-003	5.151E-003	6.567E-003	9.936E-003	1.137E-002
205	2.565E-003	5.130E-003	6.540E-003	9.885E-003	1.131E-002

TABLE 15-43

\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 2.15 FEET  
 MODAL WAVE PERIOD = 2.707 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

## YAW (RADIAN)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	9.259E-005	1.852E-004	2.361E-004	3.498E-004	4.023E-004
65	3.717E-005	7.435E-005	9.479E-005	1.411E-004	1.621E-004
101	4.040E-005	8.079E-005	1.030E-004	1.529E-004	1.758E-004
156	6.136E-005	1.227E-004	1.565E-004	2.316E-004	2.664E-004
205	8.875E-005	1.775E-004	2.263E-004	3.354E-004	3.857E-004

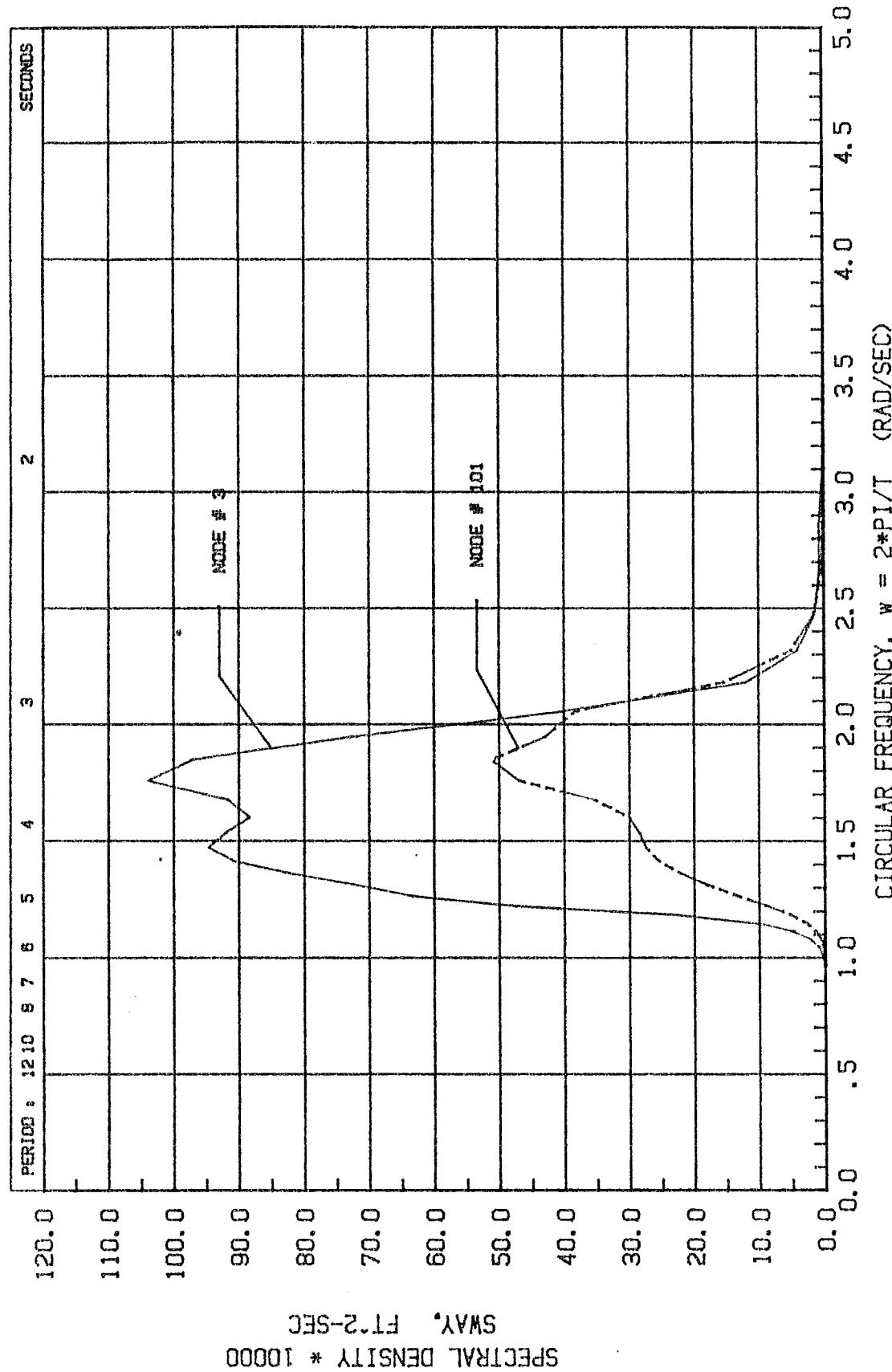
## YAW ACCELERATION (RAD/SEC^2)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	4.710E-004	9.419E-004	1.201E-003	1.794E-003	2.059E-003
65	2.199E-004	4.399E-004	5.608E-004	8.434E-004	9.665E-004
101	2.218E-004	4.435E-004	5.655E-004	8.478E-004	9.723E-004
156	2.958E-004	5.916E-004	7.543E-004	1.122E-003	1.289E-003
205	4.543E-004	9.086E-004	1.158E-003	1.731E-003	1.987E-003

## YAW JERK (RAD/SEC^3)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
3	1.167E-003	2.334E-003	2.976E-003	4.473E-003	5.126E-003
65	5.989E-004	1.198E-003	1.527E-003	2.308E-003	2.642E-003
101	5.779E-004	1.156E-003	1.474E-003	2.218E-003	2.541E-003
156	6.836E-004	1.367E-003	1.743E-003	2.600E-003	2.986E-003
205	1.128E-003	2.257E-003	2.877E-003	4.325E-003	4.957E-003

NEW I-90 BRIDGE



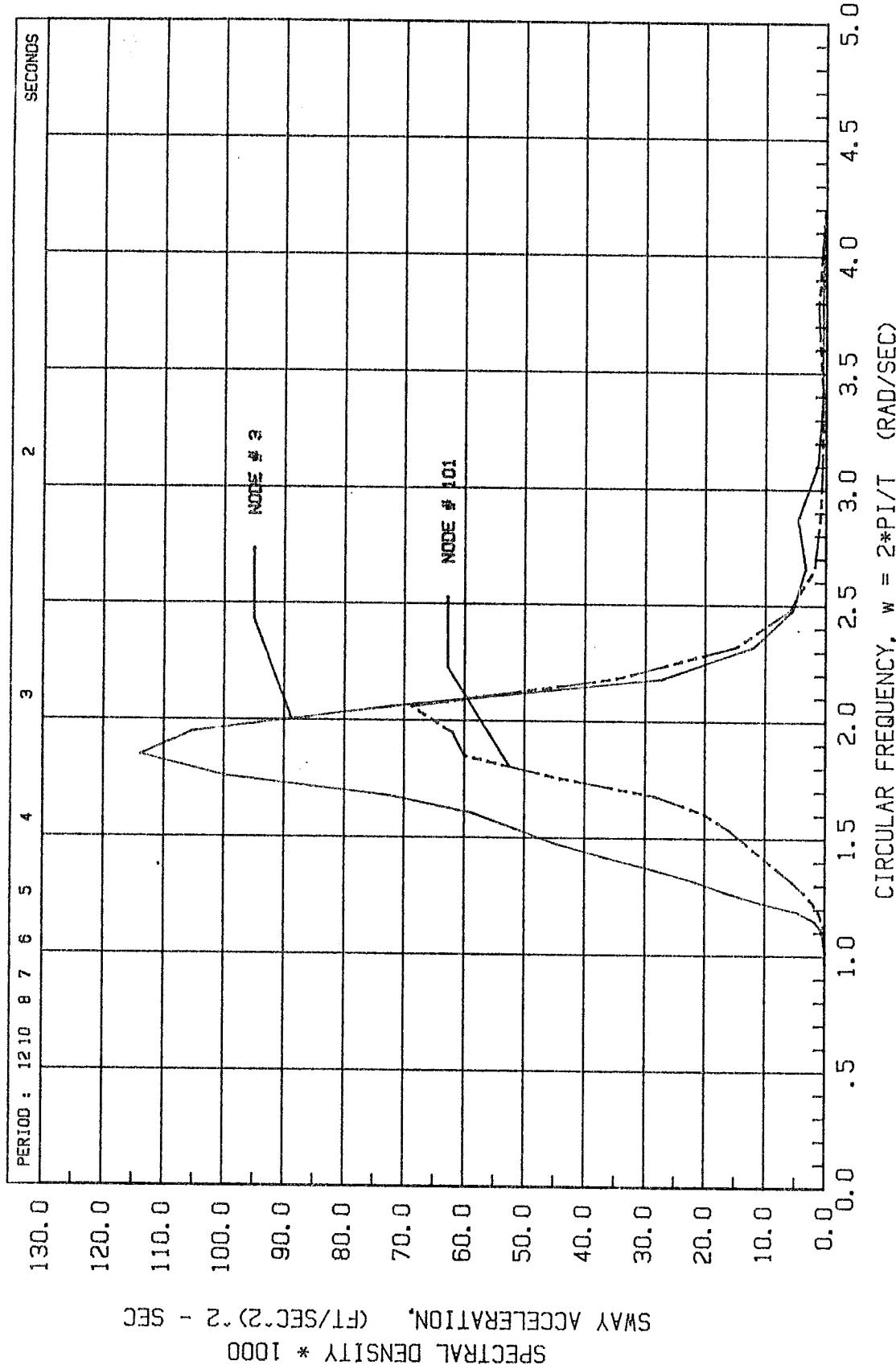
SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES < WIND FROM SOUTH >  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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 10 MAY 1983

FIGURE 15-44

FIGURE 15-44

# NEW I-90 BRIDGE



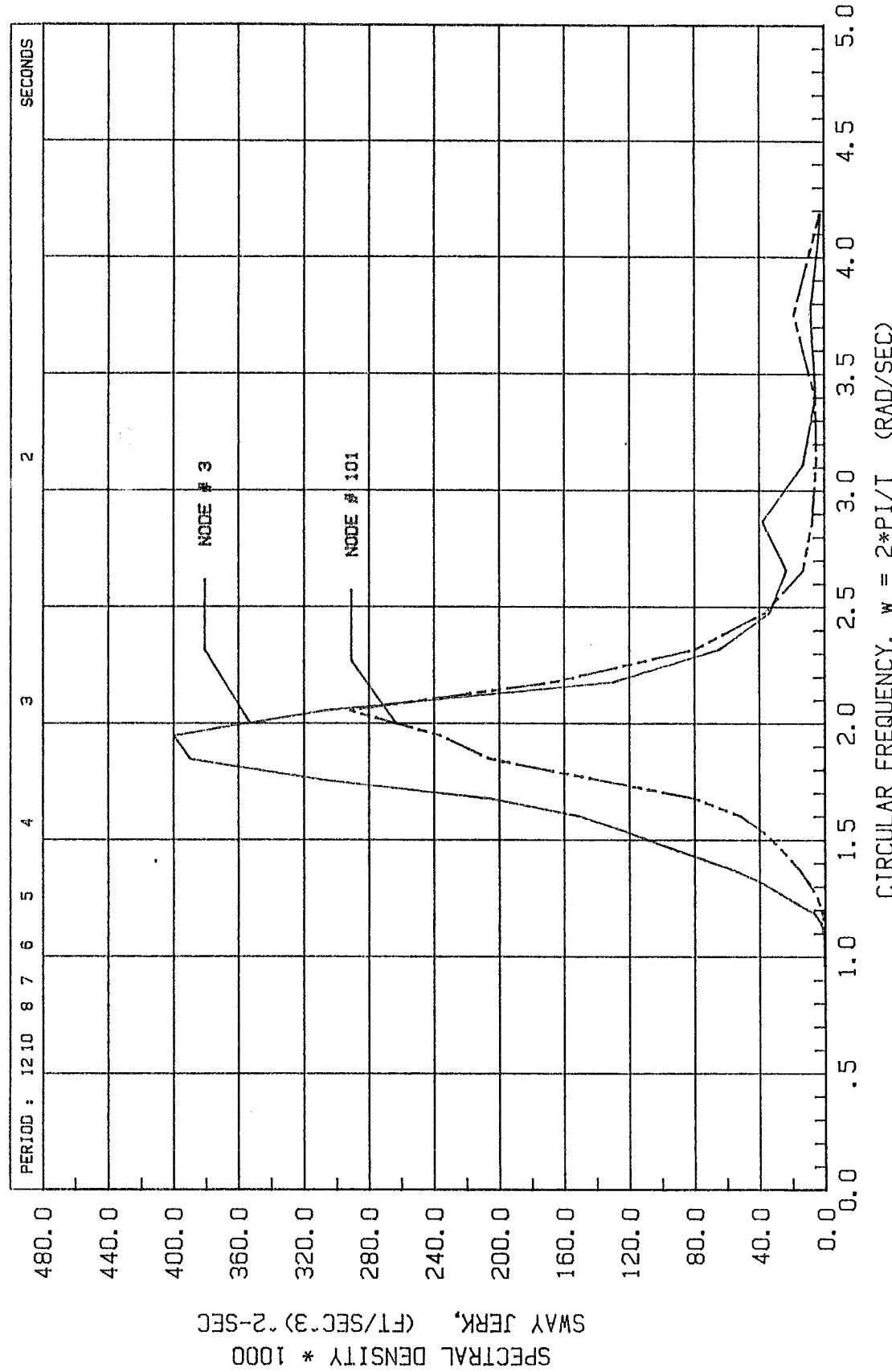
SIG. WAVE HEIGHT = 3.37 FEET   MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-45

FIGURE 15-45

# NEW I-90 BRIDGE



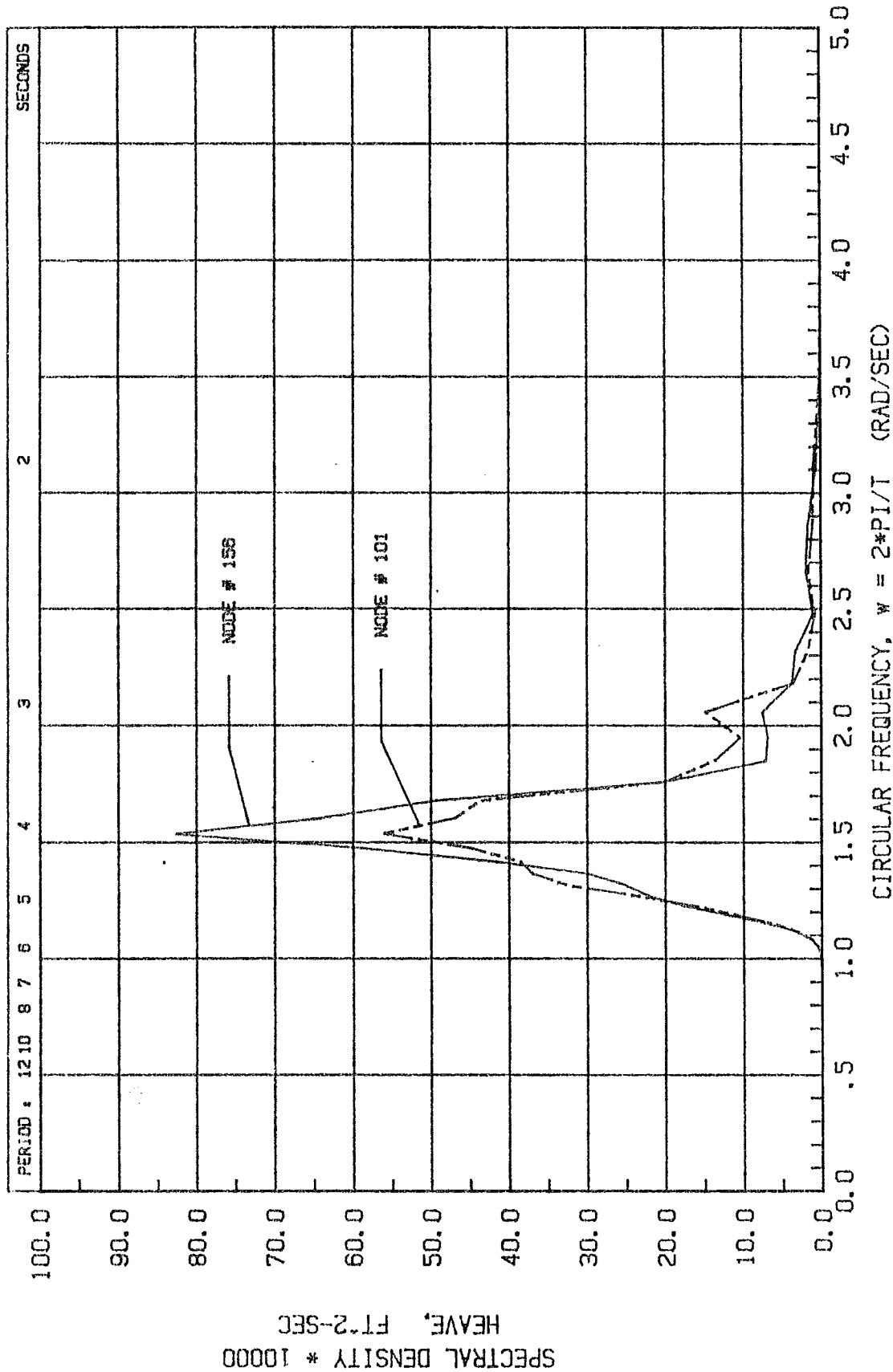
SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-46

FIGURE 15-46

# NEW I-350 BRIDGE



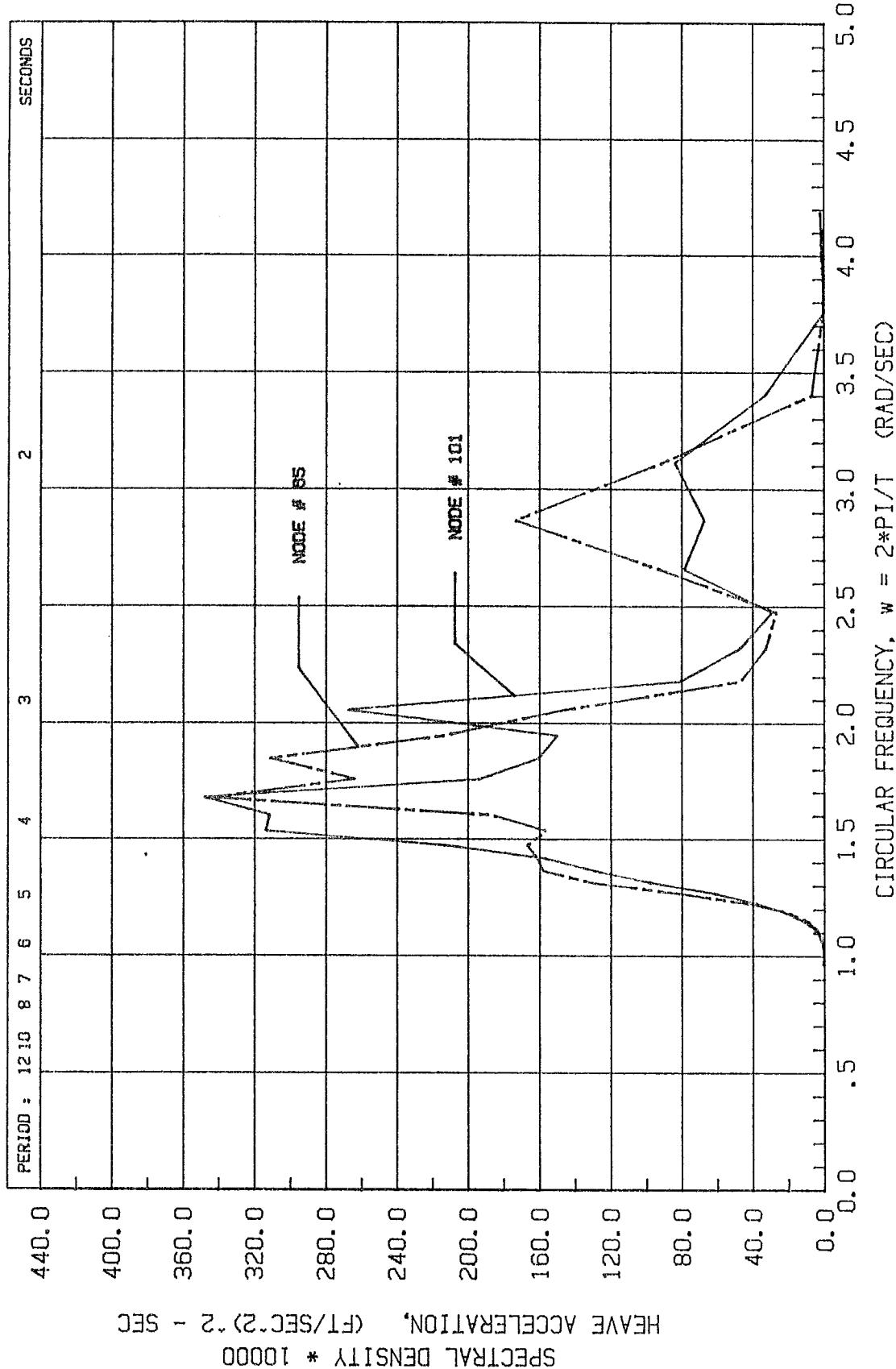
SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-47

FIGURE 15-47

# NEW I-90 BRIDGE



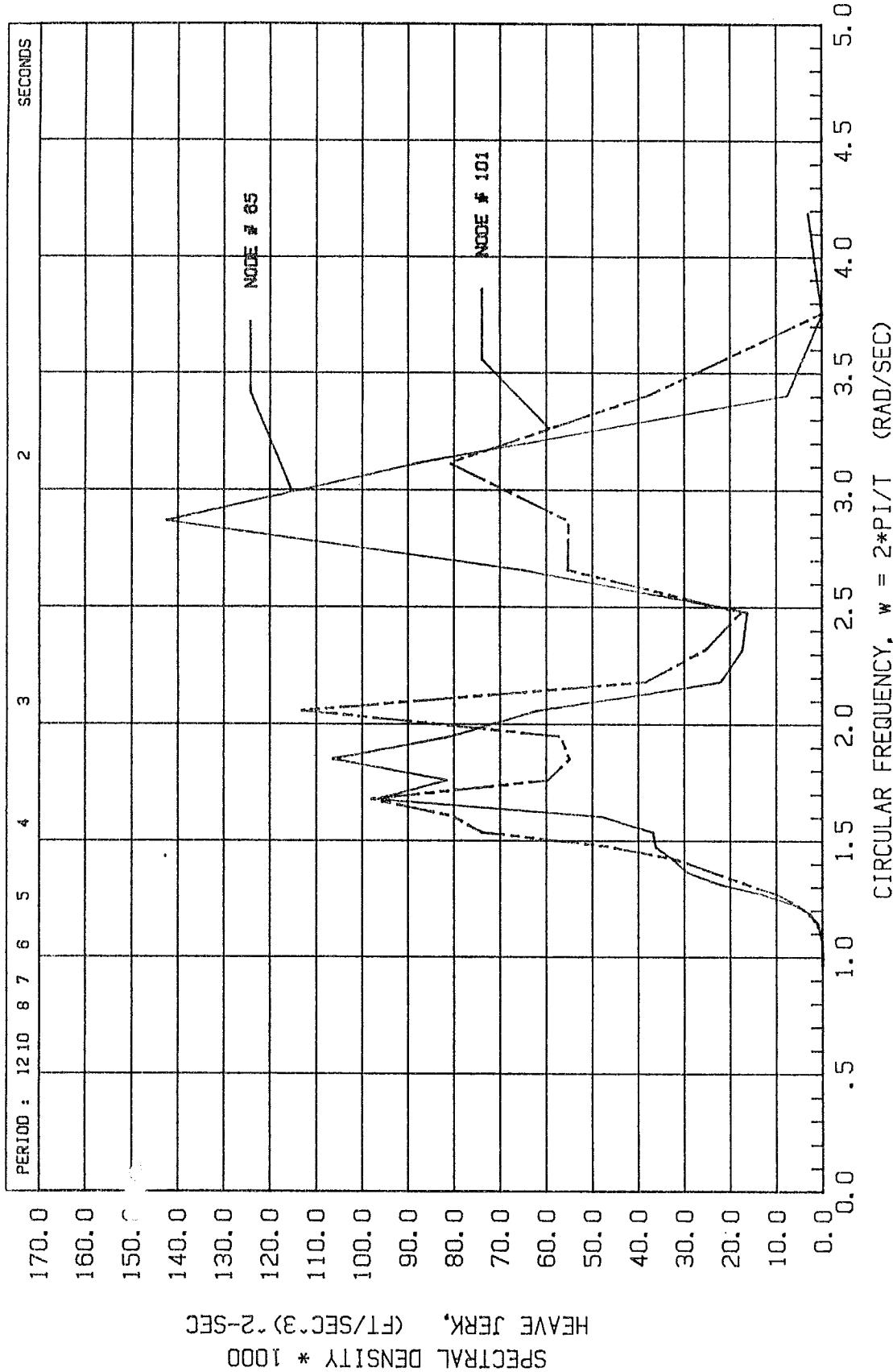
SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-48

FIGURE 15-48

# NEW I-90 BRIDGE



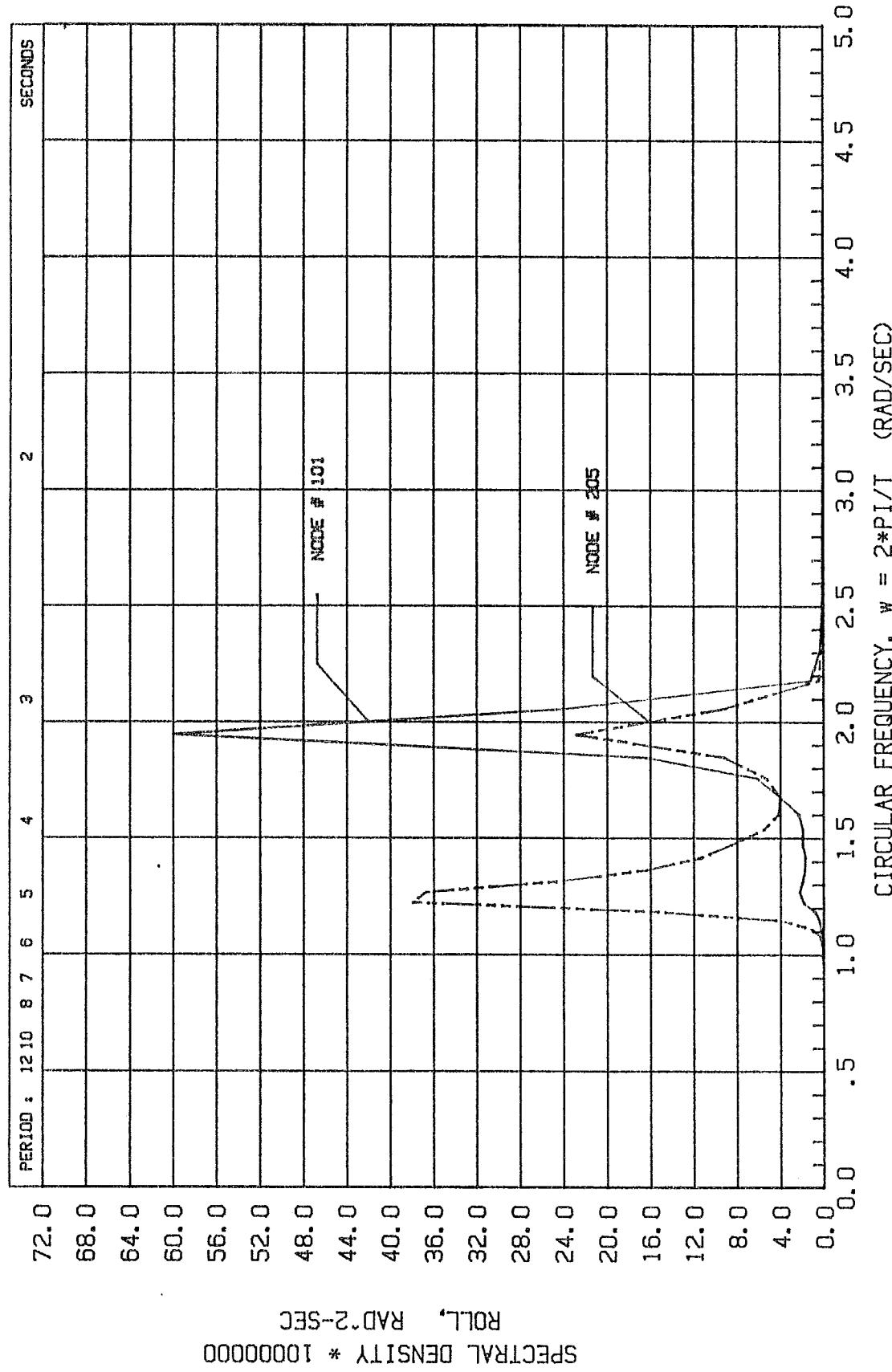
SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-49

FIGURE 15-49

# NEW I-90 BRIDGE



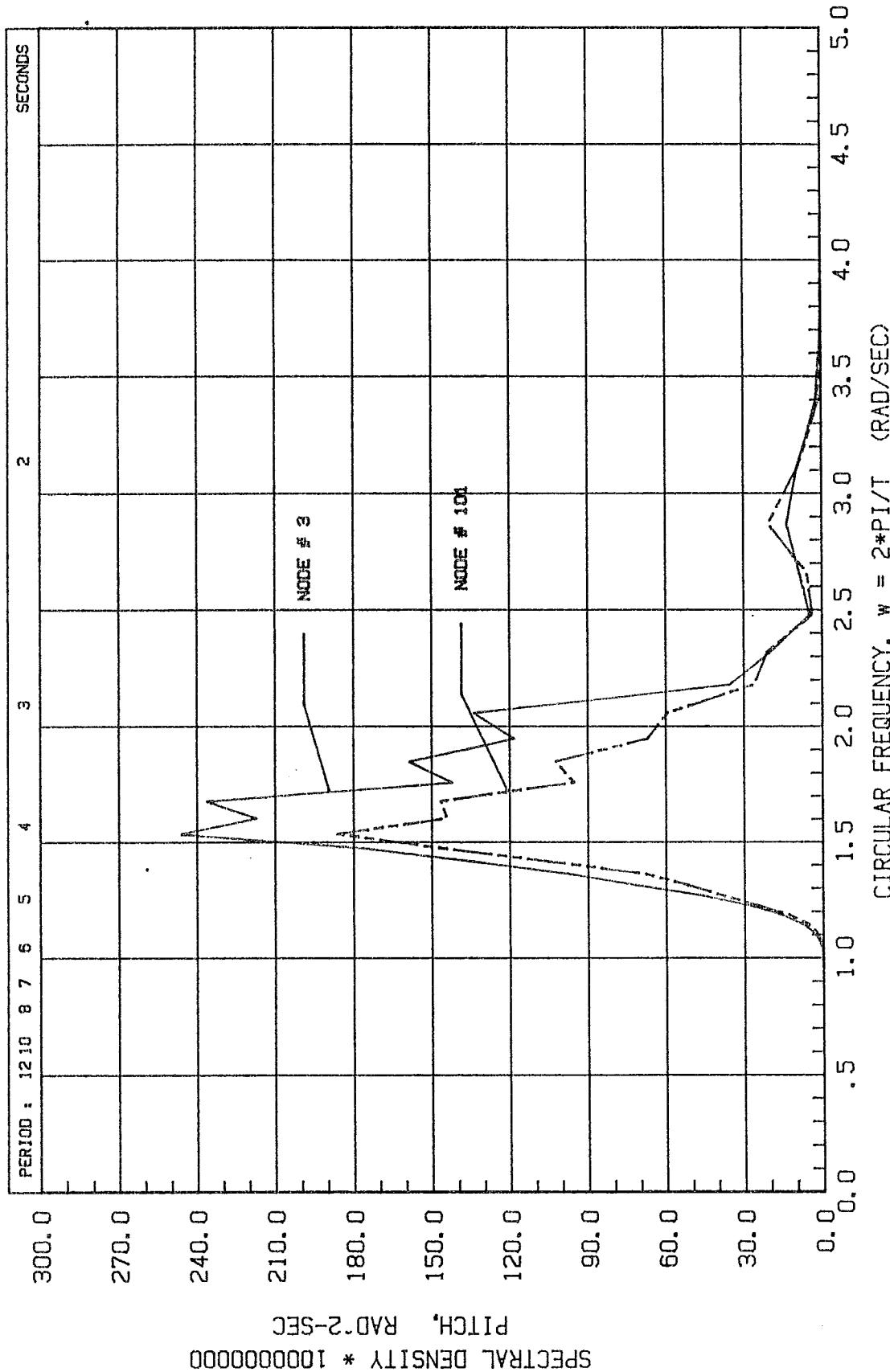
SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

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FIGURE 15-50

FIGURE 15-50

# NEW I-90 BRIDGE



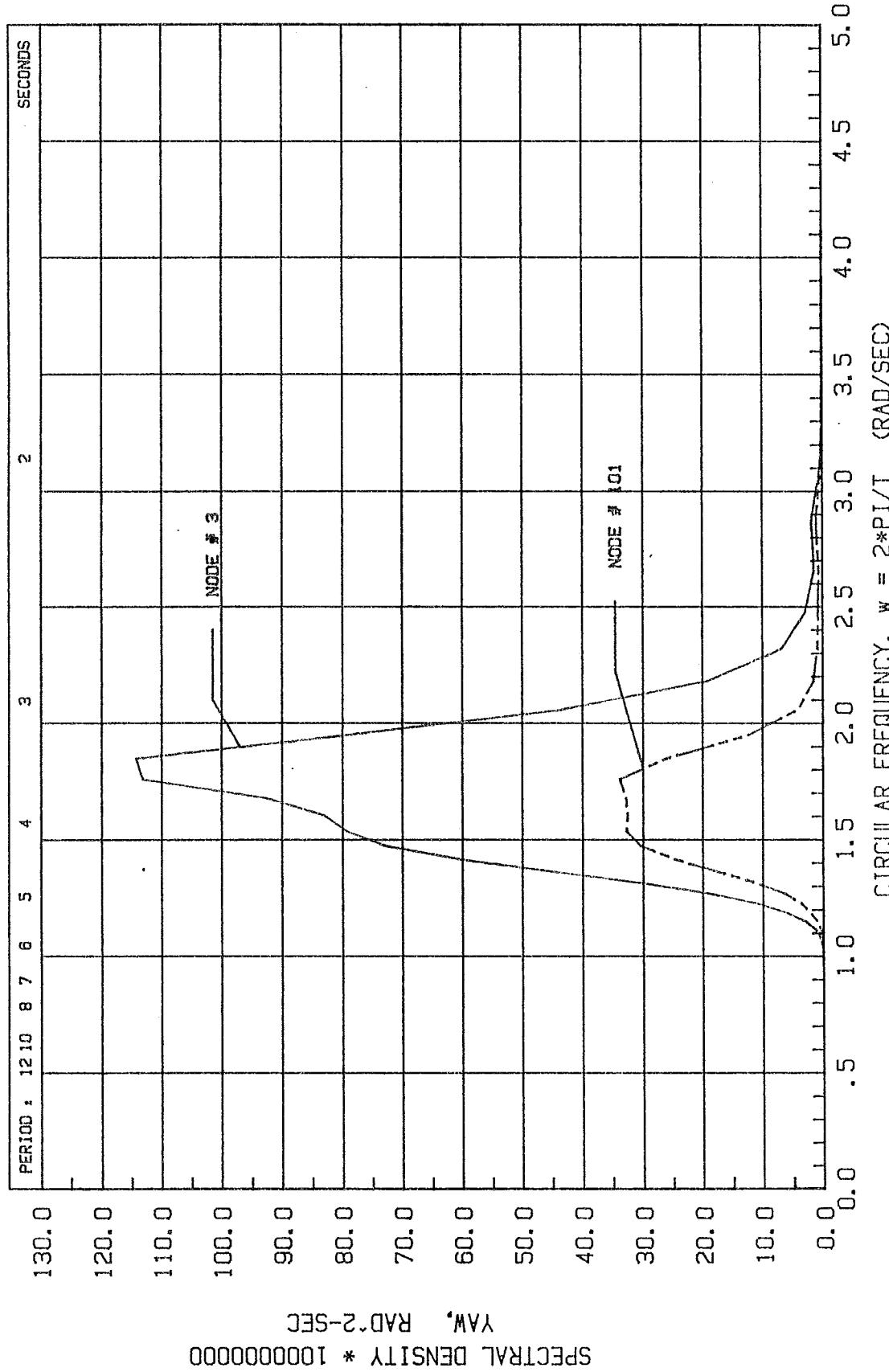
SIG. WAVE HEIGHT = 3.37 FEET   MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.  
 11 MAY 1983

FIGURE 15-51

FIGURE 15-51

NEW T-SO BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.

11 MAY 1983

FIGURE 15-52

FIGURE 15-52

#### 15.4 Mooring Line Response

Dynamic variations in the mooring line tension are given in Table 15-53, for 100 year storm conditions.

Note that for this analysis mooring system has been loaded by a static wind load from the South, and that the total pretension has been reduced by considering a lake level three feet below normal. Therefore, the tabulated results do not necessarily represent worst-case conditions for the mooring system. However, these results can be transformed with reasonable accuracy to other conditions, by assuming that anchor point motions are relatively unaffected by initial pretension.

Selected mooring line response spectra are shown in figures 15-54 and 15-55.

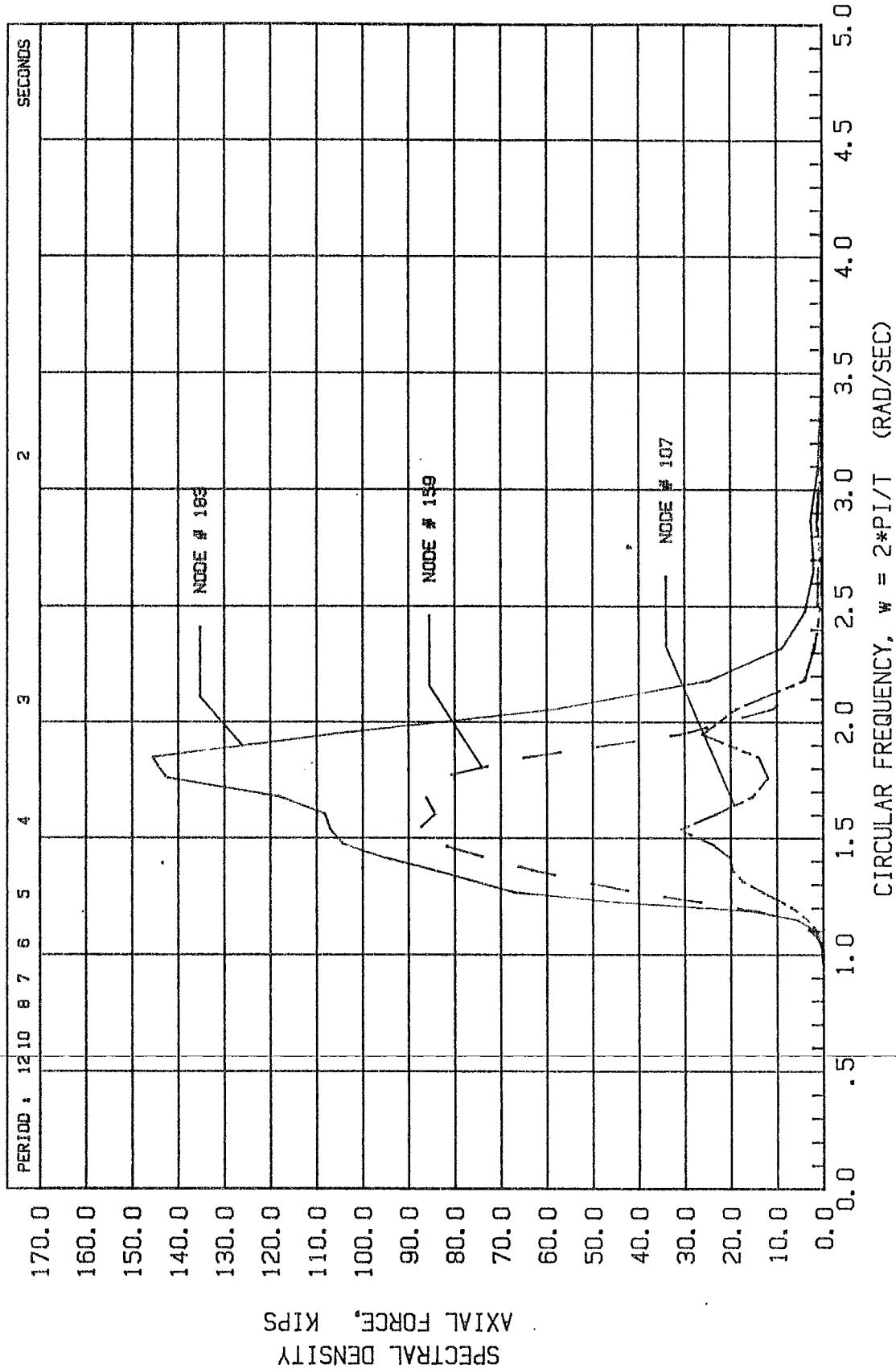
TABLE 15-53  
\*\*\*\*\*

SIGNIFICANT WAVE HEIGHT = 3.37 FEET  
 MODAL WAVE PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM THE SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

AXIAL FORCE (KIPS)

NODE	AVERAGES			EXPECTED MAXIMA	
	RMS	SIGNIFICANT	Avg 1/10 th	MOST PROBABLE	90% CONFIDENCE
13	3.558E+000	7.115E+000	9.072E+000	1.316E+001	1.522E+001
14	6.579E-001	1.316E+000	1.678E+000	2.438E+000	2.817E+000
37	4.349E+000	8.698E+000	1.109E+001	1.609E+001	1.861E+001
38	9.380E-001	1.876E+000	2.392E+000	3.475E+000	4.016E+000
61	5.078E+000	1.016E+001	1.295E+001	1.889E+001	2.181E+001
62	1.092E+000	2.184E+000	2.784E+000	4.066E+000	4.693E+000
85	5.128E+000	1.026E+001	1.308E+001	1.902E+001	2.197E+001
86	1.183E+000	2.367E+000	3.018E+000	4.392E+000	5.073E+000
107	4.350E+000	8.700E+000	1.109E+001	1.616E+001	1.867E+001
108	2.791E+000	5.581E+000	7.116E+000	1.038E+001	1.198E+001
135	5.651E+000	1.130E+001	1.441E+001	2.101E+001	2.426E+001
136	7.932E-001	1.586E+000	2.023E+000	2.949E+000	3.405E+000
159	7.493E+000	1.499E+001	1.911E+001	2.774E+001	3.206E+001
160	1.050E+000	2.101E+000	2.679E+000	3.894E+000	4.499E+000
183	9.945E+000	1.989E+001	2.536E+001	3.696E+001	4.268E+001
194	9.125E-001	1.825E+000	2.327E+000	3.394E+000	3.918E+000
202	1.087E+000	2.173E+000	2.771E+000	4.024E+000	4.651E+000
204	1.225E+001	2.451E+001	3.125E+001	4.539E+001	5.246E+001

# NEW I-90 BRIDGE



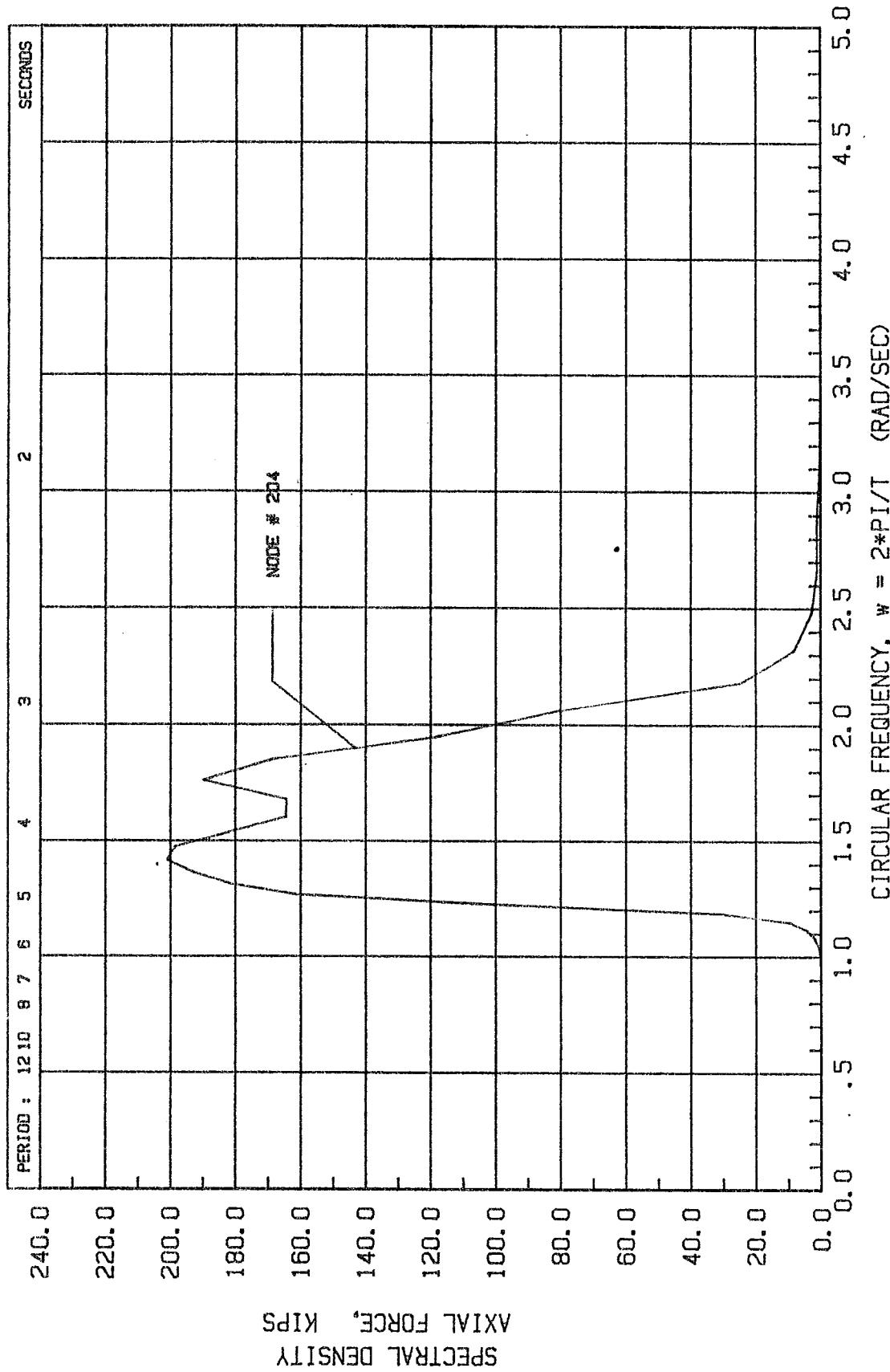
SIG. WAVE HEIGHT = 3.37 FEET      MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.  
 11 MAY 1983

FIGURE 15-54

FIGURE 15-54

# NEW I-90 BRIDGE



SIG. WAVE HEIGHT = 3.37 FEET MODAL PERIOD = 3.396 SECONDS  
 CENTRAL HEADING ANGLE = 90.0 DEGREES (WIND FROM SOUTH)  
 COSINE-POWER SPREADING TO 12th POWER  
 HYSTERETIC STRUCTURAL DAMPING = 2%

THE GLOSTEN ASSOCIATES, inc.  
 12 MAY 1983

FIGURE 15-55

FIGURE 15-55